Master's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Architecture and Design
Department of Design

Juan Francisco Soto Skretting

# Redesign of automatic baby cradle and services for relief of sleep problems

Master's thesis in Industriell design
Supervisor: Ashis Jalote Parmar
Co-supervisor: Terje Rølvåg
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## Master thesis for student Juan Francisco Soto Skretting

# Resign of automatic baby cradle and services for relief of sleep problems

**Background and purpose of the assignment:**

Infant cradles are designed to comply with traditional rules. That means sideways motion (roll), handcrafted designs, traditional wood and no additional features stimulating sleep.All cradles have one roll degree of freedom. The roll motion creates an unwanted sideways baby translation since the roll axis is located below the cradle. Research indicate that coupled longitudinal and vertical oscillations with 2-3 cm amplitudes, in the frequency range of 1-1.5 Hz, make kids fall asleep. Unfortunately, no existing cradle designs enable this motion.

Two cradles prototypes have been created and tested. The prototypes can be controlled from its own smartphones and are available for the developing of this master thesis. The production price of the current product is too high and need a re-design to be able to compete in the marked.

**Research questions:**

1. To investigate the design criteria's critical for the redesign of baby cradle in terms of lowering manufacturing costs, Safety critical parameters and improving usability of digital control parameters.
2. To investigate the usage context of business to business and business to customer service models for baby cradles in the healthcare market.

**Expected methodology:** Focus on the first four steps of the product development process:

- Literature research: Targeting product and service development for baby cradles
- Ideation: Target market. Existing products. Functionality. SWOT analysis. SCAMPER method.
- Product definition: Business analysis. Value proposition. Success metrics. Marketing strategy.
- Prototyping and testing : Create minimum viable product (MVP). Create prototype and test.
- Detailed Design: Refinement of prototype. Detailed product design.

**Expected results and format:** Working prototype of the cradle.

The assignment is carried out according to the "Guidelines for master's theses in Industrial Design".

Principal supervisor: Ashis Jalote Parmar
Co-supervisor: Terje Rølvåg

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NTNU, Trondheim, (0x.01.2023)

Ashis Jalote Parmar
Supervisor

Sara Brinch
Head of department

# Abstract

This thesis aims to incorporate Colicot technology in the design of an innovative baby cradle and home care services for newborn babies between 0-6 months of age. The project explores the transformative journey from research to the development of a prototype, focusing on how the cradle can function as a service and incorporate to a broader range of parents, including those with colicky infants. Extensive research and user feedback highlight the significance of considering crucial factors and aligning the cradle's functionality with changing baby sleeping patterns.

Through professional input and the creation of design attributes, a promising design is selected as the basis for the prototype. While the prototype is still under development and requires further refinement, it represents the practical application of findings and lays the foundation for future iterations and improvements

## Sammendrag

Denne masteroppgaven har som mål å utnytte ColiCot teknologien i designet av en vugge og hjemmetjenester for barn mellom 0 og 6 måneder gammel. Prosjektet viser utviklingen fra undersøkelse til utvikling av en prototype, som fokuserer på hvordan vuggen kunne fungere som en tjeneste, og omfatter et bredere utvalg av foreldre, inkludert de med spedbarn med kolikk. Undersøkelser og tilbakemeldinger fra brukere fremhever betydningen av å vurdere avgjørende faktorer og tilpasse vugges funksjonalitet med de skiftende spedbarn- søvnmønster.

Gjennom profesjonelt innspill og utforming av design attributter, det velges en lovende design som grunnlag for prototyper. Selv om prototypen fortsetter under utvikling og krever videreutvikling, viser den hvordan det som ble funnet ble implementert i praksis og legger grunnlaget for fremtidige iterasjoner og forbedringer.

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# INTRODUCTION

## 1.1 Project context and motivation:

The journey of parenthood has opened my eyes to the challenges faced by parents of infants with colic, and the significant impact it can have on their sleep and well-being. Inspired by the experiences of others, I embarked on a project with Colicot AS, a company dedicated to developing a cradle that offers relief and support to parents dealing with colicky babies. Terje Rølvåg, the patent owner and a professor at NTNU, started the creation of the cradle in 2010, but after some years of development it was put on hold. Through this thesis I aim to develop the product and the service around it. With the goal of revitalizing this product and increasing the possibilities of turning it into a reality.

Infant cradles are designed to comply with traditional rules. That means sideways motion (roll), handcrafted designs, traditional wood and no additional features stimulating sleep. Cradles have typically one roll degree of freedom. The roll motion creates an unwanted sideways baby translation since the roll axis is located below the cradle. Research indicates that coupled longitudinal and vertical oscillations with 2-3 cm amplitudes, in the frequency range of 1-1.5 Hz, make kids fall asleep.

While previous students have explored various aspects of the cradle through their master's projects and created prototypes, one key perspective remains unexplored—the potential for creating a comprehensive service around the cradle.

## 1.2 Aim of the research and research questions:

The aim of this master thesis is to incorporate Colicot technology in the design of an innovative baby cradle and home care services. The focus is on newborn babies between 0 - 6 months of age. By approaching the design from a fresh context, it is aimed to discover how the cradle can effectively address the needs of users.

During the initial research phase, the aim was further refined, and the design questions were changed to ensure that we address the right problem and provide the optimal solution. This work was divided into two key research questions:

***RQ1: To investigate design of baby cradles for better mobility and addressing needs of user context.***

The first research question was formulated with the product in mind, considering how the product should be when used in a new context as a service. It is intended to explore the implications this new context has on the design and how it should shape the product specifications based on the specific needs of that context.

***RQ2: To design home care services for ColiCot which are connected with existing public health services.***

The second research question centers around the service aspect of the project. It is meant to examine how the service can establish connections with people and explore the feasibility of utilizing existing systems in Norway to facilitate and distribute the cradle. Furthermore, it is intended to gain insights into the implementation of new products within the health sector.

## 1.3 Outline of the thesis:

Chapter one is an introduction, providing context, motivation, and outlining the goals of the research. The second chapter explains the methodology employed and how different approaches were combined. In the third chapter, a literature review is conducted to gather important information relevant to the development of the service and product.

Chapter four focuses on investigating the users, exploring existing relevant technologies, and examining available products in the market. Chapter five describes the entire development process, starting from problem definition and ideation, followed by obtaining feedback and creating a new concept. This chapter also explores the product's development and its integration with the service.

Chapter six discusses the research questions, addresses limitations and challenges encountered, and reflects on the process. It also incorporates key insights gained throughout the project that could be beneficial for other designers working on similar projects. Finally, chapter seven presents the conclusion, summarizing the work done and presenting the results achieved.

02

# METHODOLOGY

## 2.1 Double diamond:

The Double Diamond framework, as described by the book “This is service design doing” (Stickdorn et al., 2018), offers guidance on how designers can effectively navigate the process of developing a solution by strategically diverging and converging  focus and point of view. Through the utilization of primary research, secondary research, and user studies, I embarked on a journey to gain deeper insights into the true nature of the problem at hand. This process allowed me to define more carefully the aim of the project and focus of the research questions. Subsequently, the development phase was initiated, incorporating methodologies such as service development, strategy development, and select components of the product design process, which will be expounded upon in subsequent sections.

## 2.2 Product development process:

The product development process involves the construction of a product from start to finish. Not only does this process facilitate a streamlined product launch, but it also promotes collaborative efforts across teams, emphasizing the importance of teamwork and effective communication throughout the entire process. (Raeburn, 2022)

The product development process typically consists of 6 to 7 steps, depending on how these steps are defined. Here is an example of a product development process:

1. Idea generation: Brainstorming and generating a concept for the product.
2. Product definition: Clearly scoping and defining the concept of the product.
3. Prototyping: Creating visual and physical representations of the product.
4. Initial design: Producing an initial prototype of the product.
5. Validation and testing: Developing and testing the strategy for the product.
6. Commercialization: Further refining and implementing the product.

In this particular project, the product development process was divided according to the double diamond, framework, as showing on Figure 1. The first four steps were categorized under the development phase, while the last two steps were considered part of the implementation phase. Thus, the project focused on the initial three phases of the double diamond, concentrating on the first four steps of the product development process, while leaving the implementation phase for future work.

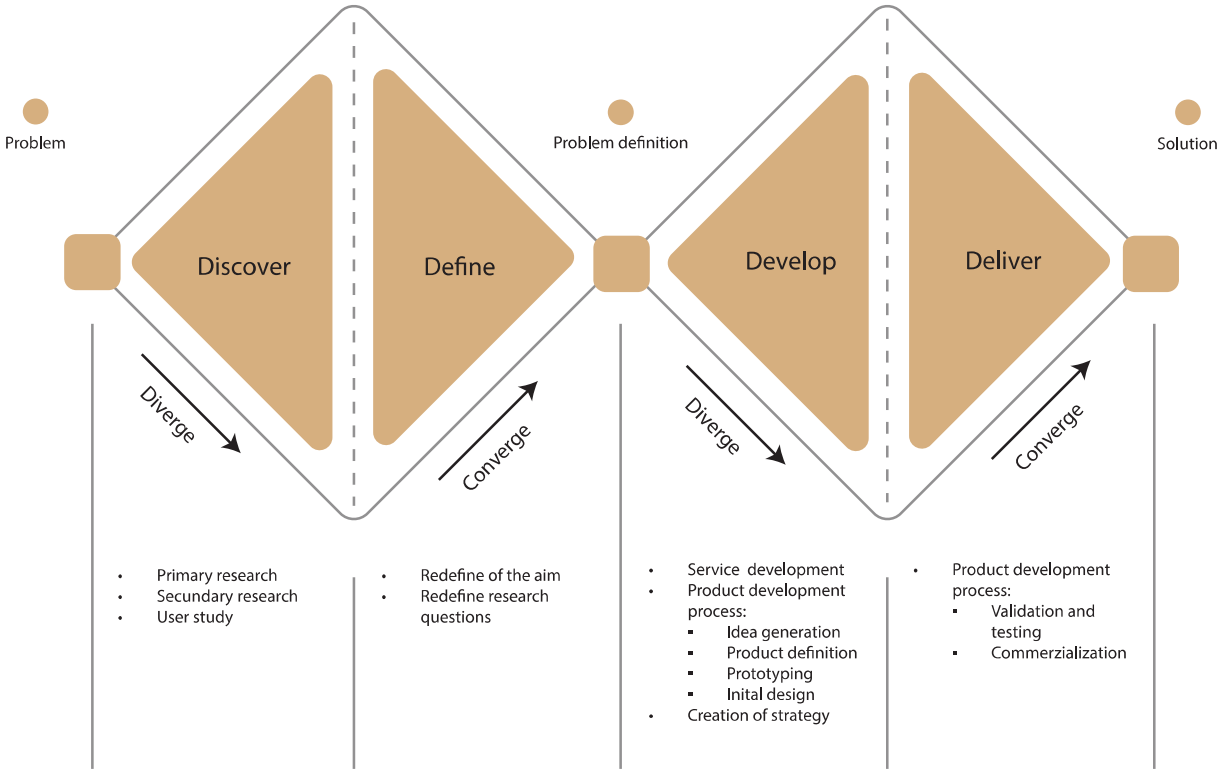



Figure 1: Double Diamond combined with Product development process

03

# SECONDARY RESEARCH

## 3.1 Research methodology:

In this literature review. I reviewed master's theses written by other students about the Colicot cradle. Furthermore, I conducted my own research utilizing search engines like Google, Google Scholar, and Scopus. The literature review was structured around distinct topics, and for each topic, I employed specific keywords to guide my search and analysis.

**Master's thesis made before:**

I got five master thesis from my supervisor that has been written before about ColiCot.

**Smart cradle design:**

To understand what has been tested, what technologies have worked and what not. Additionally the focus was on identifying the various functionalities that have been incorporated into the research and development process.

Keywords: "Smart cradle design", "Cradle design", "Automatic cradle", "Iot cradle".

**Implementation and home care design:**

This to acquire essential knowledge necessary for the successful implementation of such a product in the healthcare sector. This involved identifying key factors, requirements, and considerations relevant to the integration of the product within healthcare settings.

Keywords: "Home care for babies", "Design for health care", "Design Iot services for health care systems", "Iot and home care".

**Safety:**

How to design a safe cradle and what to take into consideration.
Keywords: "Cradles safety", "Safety factors for cradle design", "Safety standards for cradles", "ASTM F2194 for bassinets"

**Baby sleep and parent experience:**

This to acquire essential knowledge about baby sleep and how it associates with what parents feel and experience.

Keywords: "Baby sleep", "Colic baby experiences", "Colic babies", "Soothing methods for babies", "effectiveness of swinging for soothing", "sleep deprivation of parents".

## 3.2 Colicot masters from other students:

Johanne Eskerud Hovi's master thesis, "Development of a New Cradle Concept," presents the initial concept derived from prototypes provided by Colicot (Hovi, 2012). The primary users targeted are colic babies at home, but the thesis also explores the potential of using the technology for adults with insomnia. It identifies various settings, both private and public institutions, where cradles could be utilized. The requirements for the cradle encompass durability, cost, documentation, design, user-friendliness, safety, assembly, and storage. Key features include ease of use, cleaning, and storage, as well as foldability and safety. The thesis documents a design development process involving external workshops for ideation, culminating in the design depicted in Figure 2. The recommendations and future work include conducting tests to confirm the effectiveness of the VAPA mechanism, designing a modular base cradle compatible with carry cots or car seats, developing a folding mechanism, and implementing the actuator.

Dag Fredrik Nedberg's master thesis, "Vibrations' Influence on Human Physiology," investigates the impact of low-frequency vibrations on the human body (Nedberg, 2015). The study involved 36 students who participated in an experiment. A framed mattress was suspended above the floor using ropes attached to a ceiling crane to simulate oscillations. The findings indicate that the test subjects did not

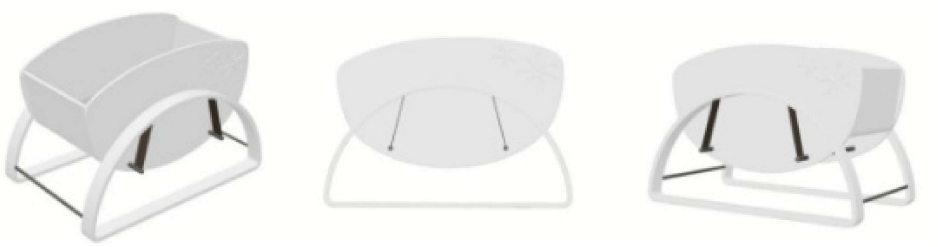


Figure 2: Hovi's Final desing

find high-magnitude vibrations comfortable, but they experienced a sense of relaxation with low-magnitude vibrations.

Christian Borner's master thesis, "Colic Crib Testing," aimed to develop a suitable test procedure and create conditions for valid test results, execution, and evaluation of tests (Börner, 2016). Borner compared the ColiCot prototype with other colic treatments and provided an explanation of the Colicot prototype. Once a testing procedure was established, it was determined that a sound level exceeding 65dB accompanied by noticeable movements indicated the child was crying. Conversely, minimal movements and a sound level below 65dB indicated that the child was either sleeping or calm. A camera was used for the movement testing.

Several technical modifications are recommended to improve the testing process:

- Reduce the weight and improve the handling of the cradle to facilitate movement by a single person.
- Reduce the cost of the cradle components.
- Address the noise and insufficient strength of the actuator to maintain a constant speed.
- Improve the quality of the wood, as it showed signs of wear shortly after production.
- Enhance the enclosure of the electronics for improved usability.

Future work suggestions include:

- Incorporating a monitoring system to prevent sudden infant death syndrome.
- Making changes to the application used to control the cradle.
- Developing a "colic guide" to educate parents about colic.
- Exploring the possibility of offering the cradle for rental purposes.

Johanna Maria Bech's master thesis, titled "Software Development for Colic Crib Testing," focuses on the further development of the ColiCot cradle app to enhance user value (Bech, 2016). The current prototype utilizes the phone's microphone, which may not provide accurate results. The cradle operates by generating resonance through a rotating motor, and its resonant frequency remains independent of the weight on the cradle. The motor's speed is set at 65 rounds per minute (rpm) and is a brushless electrically commutated (EC) flat motor with an eccentric arm. Attempts to adjust the speed for resonance were unsuccessful due to the motor's low response time.

User testing with two families indicated a positive response towards connecting the cradle to Spotify, suggesting that integrating baby call functionality could enhance user value. It is noted that each infant may have an individual optimal movement pattern, and parents should be able to experiment with different speeds.

Recommendations for further app development include:

- Conducting more user testing to validate that the app meets user needs.
- Adding the ability to change the order of sounds/songs.
- Integrating the app with Spotify.
- Extending the database to include a correct key ID.
- Controlling the motor via a network other

than Wi-Fi, preferably through Bluetooth.
- Implementing a baby call function.
- Developing a function to identify optimal movement patterns.
- Considering a motor and sensor change to achieve the resonant frequency.
- Removing the function for storing sound files.

The master thesis by Synnøve Bolstad Eri and Hilde Melvåg, titled “Colic Crib Testing,” (Mevåg, 2014) aims to investigate whether there are differences in sleep patterns between colicky and non-colicky infants using the ColiCot cradle compared to infants not using the cradle. The testing specifically focuses on colicky infants aged 4 weeks to 4 months, excluding babies with abnormalities or prematurity. The study concludes that the results of the Colicot study could be beneficial to participants and others in similar situations, with minimal risk of harm or discomfort. The thesis also emphasizes the need for special attention to address potential conflicting interests among the personnel involved.

## 3.3 Smart baby cradle designs differences:

The majority of the articles reviewed (Hiremath & Venkataratnam, 2017; Jabbar et al., 2019; Joshi & Mehetre, 2017; Pratap et al., 2021; Prusty et al., 2020) depict cradle designs with a rolling motion along the traditional axis, activated by sound detection. Common methods for swinging the cradle include motors directly attached to the hinges or a motor that pulls the cradle to create resonance. One article introduces the use of solenoids for swinging the cradle(Lu et al., 1997), which offers quiet and controlled movement. However, the safety of this solution in terms of current and magnetic field strength in the coils has not been thoroughly tested. Almost the cradles mentioned in the articles are designed to be used with a corresponding app.
Differences among the designs arise in the incorporation of additional functionalities, such as video monitoring(Symon et al., 2017) (Joshi & Mehetre, 2017), ultrasonic sensors and accelerometers (Hiremath & Venkataratnam, 2017), motion sensors and surface temperature sensors (Nawaz), air quality sensor, infrared temperature sensor, and a humidity sensor (Xie, 2019), or advanced algorithms and technology for cry recognition(Chao et al., 2015).

A common pattern is that these cradles serve as monitoring systems, utilizing both movement and sound to assist in the baby’s sleep. They are not specifically tailored to a particular type of parent or service but rather offer a monitoring system integrated into a cradle.

## 3.4 Implementation of Iot systems on home care sevices:

While there is a growing trend of IoT systems in the healthcare sector, it is primarily focused on services for the elderly, and there is limited information available regarding IoT services specifically designed for babies. However, many of the principles and challenges discussed in the articles can be applied to the development of IoT healthcare systems for infants.

In the healthcare context, the home is considered a crucial setting that prioritizes individual privacy. Therefore, privacy and security considerations play a vital role in the development of home care systems (Cavoukian, 2010).
The goal of home care systems is to enhance the efficiency and effectiveness of healthcare services, ultimately improving the quality of life for patients and reducing costs. Enabling individuals to self-manage and monitor their health conditions promotes independent living and empowers individuals through disease prevention, health promotion, and self-management of their conditions (Philip et al., 2021).

## 3.5 Safety consideration by making a baby cradle:

In this paper the safety of the cradle is divided on two categories: Physical safety and virtual safety.

**Virtual safety:**

When evaluating information and communication technologies, it is crucial to recognize that privacy encompasses a broader range of protections beyond just security. This concept, referred to as “SmartPrivacy,” emphasizes the importance of incorporating robust technological security features (“Privacy by Design”) to safeguard against data breaches (Cavoukian, 2010). It is essential to ensure the security of IoT devices and the systems they connect to, including sensors, devices, gateways, and IoT services. This involves establishing trustworthiness, protecting user identity, safety, and privacy (Philip et al., 2021).

The lack of trust in IoT devices regarding data protection, privacy, and safety has been identified as a significant barrier to their widespread adoption among end-users. Addressing this issue is crucial for enhancing trust among individuals utilizing IoT devices and systems (Philip et al., 2021).

Various quality factors can be employed to quantify the Quality of Service (QoS) in distributed systems. Numerous Quality Models have been proposed to identify QoS metrics, and one such model is the ISO/IEC 25010 quality model ISO/IEC (2010). This model defines QoS metrics, including functional stability, performance, compatibility, usability, reliability, security, maintainability, modularity, scalability, and portability (Philip et al., 2021).

**Physical safety:**

One international standard found was the ASTM F2194 (ASTM, 2022). Meeting international standards is important to make a safe product and gives security to users that will use it. The ASTM standard includes performance requirements specific to bassinets and cradles, general performance requirements, and labeling requirements. It also shows tests to meet the requirements.

**Effects of Whole-Body Vibration on Infants:**

Limited studies have been conducted on the effects of whole-body vibration on infants. One study conducted at the University of Western Ontario in 1973 found that infants as young as two months fell asleep most quickly when exposed to vibrations with a frequency of 1.5 Hz and an amplitude of three inches. However, it is important to monitor the frequencies present in a child’s cradle, as frequencies below 1 Hz may cause nausea, while frequencies above 2 Hz could be harmful (See appendix A).

## 3.6 Baby sleep, colic babies and parent experience:

During the early months of life, infants have significant changes in their sleep patterns and behaviors. Understanding these changes and implementing appropriate strategies can help parents promote healthy sleep habits in their babies. Here are some key points to consider:

**Sleep Hormone Production:**

Around 3 months of age, infants begin to produce the sleep hormone melatonin, which aids in longer stretches of sleep at night. Establishing a fixed wake-up time in the morning becomes important, and bedtime can gradually be shifted to earlier in the evening (UiO, 2022) .

**Transitioning Sleep Support:**

As infants grow older, gradually reducing the support provided during bedtime can help them fall back asleep when they wake up more frequently at night (typically between 4-6 months

of age). This transition can involve moving from nursing to sleep to rocking, and eventually to simply placing a hand on the child's chest. These awakenings are a natural part of development and may not necessarily indicate hunger (UiO, 2022).

**Whining and Crying:**

It is common for infants to whine or cry before falling asleep. However, an overtired child may have difficulty calming down and take longer to fall asleep. Ensuring that the child is not overly tired can help promote easier and quicker sleep (UiO, 2022).

**Seeking Health System Support:**

Parents should contact the health system if they suspect their child has a medical condition contributing to sleep problems, if their child snores heavily with breathing pauses during sleep, if they are uncertain about following typical advice, or if they require assistance in resolving their child's sleep issues(UiO, 2022).

**Typical Sleep Time for Babies Between 0-8 Months of Age:**

The amount of sleep required by infants varies depending on their age. Here is a general guideline (Lein, 2019):

- Newborns (0-1 month): 15-18 hours of sleep. Newborns do not have a fixed circadian rhythm and tend to sleep in intervals of two to four hours both during the day and at night.
- 1-4 months: 14-15 hours of sleep. Infants in this age range still need frequent feedings, including during the night.
- 4-8 months: 14-15 hours of sleep. By this age, infants start to develop a circadian rhythm.

**Soothing Infants:**

The "Easy Way to Soothe the Baby" manual, based on "The Happiest Baby on the Block," highlights the importance of understanding infants' circadian rhythm, causes of crying, sleep regulation, and the use of the 4S techniques: swaddling, side or stomach positions, shushing, swinging, and sucking (Ozturk Donmez & Bayik Temel, 2019). A study showed that teaching mothers these techniques effectively developed self-regulation behaviors in infants aged 3-23 weeks. Swinging, both in arms and on a blanket, was found to be effective in reducing crying durations in infants, including those with colic (Duygu, 2015)

**Sleep-Wake Patterns and Behavioral Insomnia:**

Sleep-wake patterns undergo significant changes during the first year of an infant's life. Nighttime sleep becomes more consolidated, while daytime sleep decreases. Infants who rely on physical contact or active parental involvement to fall asleep are more likely to wake up frequently and require assistance to return to sleep. These sleep problems, known as behavioral insomnia, can be resolved through behavioral interventions that encourage infants to fall asleep and resume sleep with minimal parental involvement (Sadeh & Sivan, 2009).

**Colic, sleep problems, and parents' experiences:**

Colic, characterized by paroxysmal abdominal pain and crying, is common in infants during their first few months. Colic may affect sleep, with decreased daytime sleep and increased night wakings reported. Establishing good sleep hygiene through parental guidance is recommended for infants with colic and post-colic sleep problems (Sadeh & Sivan, 2009).

Infantile colic, affecting approximately 10% of newborns, can be a challenging experience for parents. The prolonged crying of more than three hours per day, often starting in the first

three weeks of life and lasting until 3-4 months, can cause stress and feelings of incompetence in caregivers. Persistent crying may lead to increased risk of exposure to physical violence and can disrupt family relations, creating chaos in family life (Landgren & Hallstrom, 2011).

Parents of colicky babies try various strategies to soothe their baby, including holding, swinging, and feeding. However, the constant crying can make parents feel lonely, powerless, and frustrated. Mothers, in particular, may experience a sense of isolation if they cannot share the burden with their partner. The experience of colic can hinder the closeness and relaxation parents had hoped for, adding to their emotional challenges (Landgren & Hallstrom, 2011).

Mothers who have experienced premature labor face specific difficulties in caring for their infants at home during the postnatal period. Challenges include diaper use, bathing, umbilical cord care, baby feeding, skin-to-skin contact, and recognizing newborn crying. These mothers often lack self-confidence in baby care and require support from health professionals. Developing clinical guidelines for postnatal care of preterm babies can alleviate concerns, reduce hospital stays, and minimize morbidity risks. It is important for nurses to provide adequate information and guidance on home care for preterm babies (Ozberk et al., 2021).

Differentiating between sleep problems and excessive crying in infants during the first six months can be challenging. However, as sleep-wake cycles become established between 3-6 months, the prevalence of sleep problems becomes more apparent. Sleep and cry-fuss issues drive healthcare usage, particularly for disadvantaged women who face barriers in seeking help. Infant sleep problems are associated with postnatal depression (PND), affecting 10-15% of mothers. There is a clear link between cry-fuss behavior and PND (Bayer et al., 2007).

Around four months, sleep disruption is common, with infants waking frequently. Some infants sleep in their own cribs, while others sleep in parents' rooms or co-sleep. Mothers tend to be the primary caregivers at night, with minimal involvement from fathers. Approximately one-third of mothers report sleep problems in early infancy, which typically begin around two months. These sleep problems persist between three and six months and can have negative impacts on mothers' mental and physical health, regardless of socioeconomic status (Bayer et al., 2007).

Poor maternal physical and mental health, along with tiredness and infant difficulties in the first six months, are interconnected. Mothers who experience better sleep quality are less likely to face mental health issues related to infant sleep problems. Primary care professionals should routinely inquire about infant sleep problems and maternal health. Implementing effective sleep strategies, such as changing sleep associations and promoting self-settling, can reduce both infant sleep problems and maternal depression (Bayer et al., 2007).

Addressing maternal tiredness can lead to improved caregiving, and early interventions can predict better infant self-soothing at 12 months. Providing anticipatory guidance for sleep in the first months can enhance the overall health and well-being of parents and children (Bayer et al., 2007).

## 3.7 Innovation on health care

Commercial actors play a crucial role in the innovation process within the healthcare sector. It is essential to involve them early on, with healthcare providers acting as demanding customers. These actors must define their business models and overarching goals clearly. Sufficient resources should be allocated to development and collaboration, and research should focus on measuring the impact of innovation, such as realizing gains. Early collaboration with the supplier industry is also important, where suppliers demonstrate what is achieva-

ble through technology and standards, aligning them with the healthcare system's requirements, visions, and desires. Suppliers should collaborate with demanding customers to further elevate their visions. A notable example is the PET center at Oslo University Hospital/Rikshospitalet. As innovation progresses, suppliers must be willing to deliver competitive products in a global market, particularly in the field of radiology. Development and innovation require significant resources, and the costs should be shared among many to be sustainable (Rønning, 2010).

A key challenge for increasing innovation in the healthcare sector lies in the collaboration between public healthcare institutions and private enterprises. Commercializing research findings and other ideas originating from healthcare institutions should be a primary focus. Challenges in this regard may include inadequate resources, a lack of innovation culture and motivation within healthcare organizations, insufficient expertise and resources in units dedicated to supporting commercialization efforts, uncertainty regarding legal rights associated with commercial outcomes, and difficulties related to public-private collaborations and procurement regulations. Investment in research and idea development, as well as the distribution of benefits from potential commercialization, can also pose challenges (Rønning, 2010).

Within the healthcare system, three interconnected processes can be identified: generation, implementation, and widespread adoption of innovative ideas. The generation process involves creative thinking that leads to the inception and initial pilot testing of innovative concepts in clinical, business, or service delivery realms. Implementation refers to the challenges associated with putting an idea into action and integrating it into the routine operations of a healthcare organization. The spread process focuses on accelerating or impeding the adoption of new practices across multiple organizations and eventually throughout the entire healthcare system. While creative thinking and adaptation primarily occur during idea generation, further development and enhancement take place during local implementation and as ideas spread across organizations (Plsek, 2003).

From an individual organization's perspective, these processes can occur independently or in combination and can unfold in any order. For instance, an organization may generate an innovative service delivery concept, implement it internally, and then contribute to industry-wide efforts to promote its adoption, such as presenting at national conferences. Another organization might participate in the spread process by sending a team to a conference, subsequently adapting the innovation for local implementation. At the same conference, another team may reject the idea after gaining more insights, thus ending the adoption process, while yet another team may be inspired to creatively explore service innovations in other aspects of healthcare delivery. It is worth noting that innovators, such as vendors or consultant groups, sometimes proceed directly to the spread process without first achieving successful implementation within a single organization. The complexity of the healthcare system impacts each of these processes(Plsek, 2003).

German philosopher Goethe once remarked, "To put your ideas into action is the most difficult thing in the world." One of the consequences of healthcare organizations' complexity is their remarkable resilience in the face of pressure, even when the pressure is for positive change. Ultimately, decisions to change are made by individuals within a complex system based on their personal mental models regarding the benefits and risks associated with the change. Even if those in hierarchical positions believe they can enforce change, individuals often retain the autonomy to decide how they will react. For example, a hospital administrator can mandate the implementation of a computerized order entry system, but individual physicians can choose whether to use it or continue with traditional handwritten orders (Plsek, 2003).

## 3.8 Summary and key learnings

During my secondary research, I examined master's theses authored by other students focusing on the development of the cradle. Additionally, I reviewed papers pertaining to alternative cradle designs, safety considerations, and the implementation of Internet of Things (IoT) products in the field of healthcare, and papers in relation to baby sleep and parental experience.

The analysis of the master's theses revealed a common pattern suggesting the need for a redesigned cradle with a folding mechanism. This modification would facilitate testing procedures and decrease the overall weight of the cradle. To be able to make the cradle work a combination of a movement sensor and sound readings could be employed.

It is found that ensuring the trustworthiness of the product requires both virtual and physical safety measures. The ASTM F2194 international standard can be utilized to ascertain a high level of safety for the cradle.

Sleeping patterns in infants undergo significant changes during the first few months. Notably, babies do not produce the sleep hormone melatonin until they reach three months of age. The period between four to six months is crucial for establishing healthy sleeping patterns in infants.

Various methods exist for soothing babies, such as shushing, swinging, and sucking, which have proven to be effective. Swinging at frequencies between 1-1.5 Hz has been found to induce sleep in babies.

Infantile colic disrupts family life due to prolonged crying, causing stress and feelings of powerlessness in parents. It is associated with postnatal depression in mothers. Better maternal sleep quality can alleviate related mental health issues, and addressing maternal tiredness improves caregiving. It shows that depression can be connected directly to sleep in some situations. Sleep deprivation has a real impact on physical and mental health.

Commercial actors significantly influence healthcare innovation, with challenges including inadequate resources and uncertainties around legal rights. The processes of innovation are generation, implementation, and widespread adoption of ideas. The complexity of the healthcare system impacts these processes and the decisions to make changes.

04

# PRIMARY RESEARCH

## 4.1 User study

To gain insights into the value that the ColiCot cradle could offer to users, a series of interviews were conducted. The purpose of these interviews was to explore the experiences of parents after the birth of their children, particularly those with special needs such as colic, prematurity, or illness, and to understand their perception of the cradle as a potential solution. Five interviews were conducted, involving one father, three mothers, and one couple.

Among the participants, three of the five encountered difficulties during the first few months after childbirth. The couple and one mother had infants with colic, while one other mother had a premature child. The remaining two participants had healthy infants.

From these interviews, it became evident that all parents experienced a decrease in sleep after having their babies and expressed a desire for some personal time. The parents with healthy infants appreciated the moments they spent putting their babies to sleep, despite the challenges they sometimes faced. They expressed concerns about relying too heavily on a product to facilitate their baby's sleep, as they associated the personal accomplishment of soothing their baby with positive emotions.

In contrast, the parents with colic infants shared feelings of frustration and powerlessness. One mother expressed experiencing mild depression and fear during bedtime due to her child's persistent crying. She also mentioned the lack of belief from healthcare professionals regarding her child's colic. The support received from healthcare providers was minimal in their case.

A noteworthy case was that of a mother with a premature infant. Her experiences mirrored those of parents with colic infants and, in fact, were even more challenging. Her baby required constant proximity, leaving her unable to perform essential daily tasks, such as preparing food. However, she received significant support from the municipality and healthcare services, including the loan of a sling cradle for three months. This resource was immensely helpful to her, and she appreciated the portability it offered. Additionally, she expressed that having a monitor to track her premature infant's breathing patterns would have been a dream, considering that premature infants are more susceptible to breathing issues. Such a monitor could have continued to be useful even to this day.

Through these interviews, it was confirmed that parents of infants with colic or premature infants could benefit from the Colicot cradle. However, parents with healthy infants perceived little value in the product and considered it not worth the investment. It became evident that parents of premature and colic infants faced similar challenges and shared comparable experiences. While they welcomed any assistance available, they also emphasized the importance of spending quality time with their babies and being present for them.

## 4.2 Existing products:

There were found seven different smart cradles that share some of the functionality with Colicot and one that has a similar motion structure but is not a smart cradle and needs to be used manually. A matrix has been created to compare the different functionalities of the different cradles. Four of the cradles have an app that is used in addition to the cradle. A new matrix was created to compare the functionalities on the different apps.

**Is there already a solution?**

There are some solutions that have similar functionalities of what the ColiCot wants to archive. The SNOO bassinet was created with the help of a specialist on baby sleep, and seems to be the most complete in terms of functionalities for the app. The Snoo claims to be de-

Table 1: Functionalities of products aviable on the market

| | Functionalities | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Products | Cry detection | Motion | App | Sound | Video streaming | Cradle and crib | Physical UI | Wheels | Block motion | Sleep sack | Adjust height |
| Cradlewise | ■ | ■ | ■ | ■ | ■ | ■ | | | | | |
| Moonboon with motor | | ■ | | | | | | | | | |
| SNOO bassinet | ■ | ■ | ■ | ■ | | | | | ■ | ■ | |
| Sense2Snooze Bassinet | ■ | ■ | | ■ | | | ■ | ■ | | | |
| Fisher-Price Soothing Motions Bassinet | | ■ | | ■ | | | ■ | | ■ | | |
| Mamaroo | ■ | ■ | ■ | ■ | | | ■ | | | | ■ |
| Fisher-Price Luminate Bassinet | ■ | ■ | ■ | ■ | | | ■ | | | | |
| StarAndDaisy Electric Baby Swing Cradle | | ■ | | ■ | | ■ | ■ | | ■ | | |
| Colicot | ■ | ■ | ■ | ■ | | | | | | | |

Table 2: App functionalities of products aviable on the market

| | App functionality | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Products | Baby monitor | Sleep notifications | Sleep tracking | Alert parents if crying do not stop "Time out" function. | Movement adaptability | Weaning mode | Adjust motion, sound, and cry sensitivity. | App optional | Timer | Different rockign motions |
| Cradlewise | ■ | ■ | ■ | | | | | | | |
| SNOO bassinet | | ■ | ■ | ■ | ■ | ■ | ■ | | | |
| Mamaroo | | | | | | | | ■ | ■ | ■ |
| Fisher-Price Luminate Bassinet | | ■ | ■ | | | | ■ | | | |
| Colicot | | | | | | | ■ | | ■ | |

signed to respond to your baby's cries with a sophisticated algorithm that mimics the actions of an experienced caregiver. That means that the SNOO chooses the best motion as well as the best noise to help calm the child (SNOO, 2023). What people most complain about this product is the price that is about 1700 usd, and not worth for the use of only max 6 months. As a response the SNOO implemented a renting system and created a service. As the same as ColiCot the SNOO is not suitable for a health care service. Is not easy to wash or transport and do not have enough technology to take care of ill children. Meaning that it has a much smaller customer base. The SNOO proves that a smart cradle with movement will at least add one to two hours of sleep to the parent per day. That few hours can make a big difference.

The other product that stands out from the rest is Cradlewise. This product combines a cradle and a crib, making the parents choose between a cradle or a crib before use and having up and down motion. In addition, it is the only one with a camera monitor that can be used to see the baby from the phone. Having a crib and a cradle combine is both a benefit and a drawback. When sold at a similar price, the Cradlewise can be used for up to 24 months as a crib making it more worth to buy for some parents. But experts do not recommend childs over 6 months to have moving beds as it teaches the babies to need the motion to fall asleep. They recommend transitioning to a normal crib around the 6 months of age.

## 4.3 Possible technology and products:

**Sonar technology:**

An active sonar is a sensor that sends a sound wave that bounces off an object and returns a "echo" that is read by a transducer. By determining the time between the emission of the sound pulse and its reception, the transducer can determine the range and orientation of an object. This is typically used in the mapping of the ocean(National Ocean Service, 2023). Ultrasounds are very safe for humans especially when the frequency used is higher than what a human can hear (Sleep as Android, 2017b)

An example of the use of a sonar technology is the company Sleep as android that develops an app that transforms a phone to a sonar device to track sleep. The speaker and microphone of the phone is used to create the sonar and track the abdominal movements and estimate breath rate. From the breath rate the sleep quality is determined (Sleep as Android, 2017a).

Is believed that the company VitalThis uses this technology for one of their products, the Somnify. The Somnofy is a sleep tracker with a high accuracy and demonstrates how powerful the sleep tracking capabilities of this technology (Somnofy).

**Corral ai:**

Corral ai is a toolkit for development of machine learning products. This device allows local machine learning calculations without the use of a server (CorralAI). An example is the use of a raspberry pi board to run an image recognition algorithm. This could have not been possible before (DataSlayer, 2023).

## 4.4 Summary and key learnings:

For the primary research, we conducted interviews and examined other products and explored potential technologies that could be utilized with the cradle.

The main findings indicate that the cradle can benefit not only parents of colicky babies but also other types of parents. It was confirmed that the cradle is not highly valued by parents with healthy infants, but it holds significant value for parents of colicky or premature babies. These findings align with what we discovered in the secondary research.

I discovered existing products with similar purposes, but none of them are specifically designed to function within a service context. One notable competitor is the SNOO, although it comes with a high price tag. The SNOO incorporates critical features that align with our secondary research findings, such as the weaning mode and time out function. This realization emphasizes the importance of aligning the cradle's functions with the changing sleeping patterns identified in the secondary research.

Two technologies were identified as interesting for enhancing the value of the cradle. The first is sonar technology, which has proven to be exceptionally accurate in sleep monitoring. Implementing this technology could greatly enhance the value of the new product. The second technology is corral AI, which could be incorporated to improve system reliability, although it is not essential.

05

# CONCEPT DEVELOPMENT

## 5.1 Problem framing:

Through both primary and secondary research, it has been found that parents of colicky and premature infants face significant challenges due to sleep deprivation, leading to potential distress and mental health issues, including depression and increased aggression. These impacts disrupt parents' daily functioning and negatively affect their mental health, and are most pronounced for parents of infants with special needs.

The analysis of secondary sources, such as master's theses and research papers on alternative cradle designs and IoT in healthcare, highlighted the need for a redesigned, service-oriented cradle with a folding mechanism and lighter weight. Incorporating movement sensors and sound sensors were enough to make the cradle functional . The studies emphasized the importance of ensuring physical and virtual safety, adhering to standards like ASTM F2194, and aligning the cradle's functions with infants' changing sleep patterns.

Primary research corroborated these findings and revealed that existing products, like the SNOO, are not specifically designed within a service context and may be cost-prohibitive. The identified gap in the market is for a cradle that can benefit not just parents of colicky babies, but also other parent types, particularly those with infants requiring more attention. Technologies such as sonar technology for sleep monitoring and corral AI for system reliability were identified as potential enhancements for this solution.

The objective of this project is to develop a service-oriented, mobile cradle that incorporates these insights and is customized to improve the sleep quality of parents with babies with special needs, by improving their overall mental wellbeing. The key assumptions are that parents will be open to using such a product and that it will plait will effectively improve their sleep and daily functioning.
The key assumptions are that parents will be open to using such a product and that it will effectively improve their sleep and daily functioning. In addition, it is assumed that the cradle will cooperate seamlessly with healthcare personnel and that parents will comply with the given instructions for using the product
Potential constraints include design and safety considerations, alignment with the complex processes of healthcare innovation, and possible uncertainties around legal rights and resources. It aims to decrease the incidence of parental distress and mental health issues by significantly improving their sleep quality, which could be measured through user feedback and sleep quality indices.

## 5.2 Concept version 1:

### Mapping of possible users:

From the insight gathered in previous chapters I found that the deprivation of sleep experience can have repercussions on the mental health of the parents. I believe that the use of the cradle can be expanded to other families in similar situations that face the same problem. Figure 3 shows all the different possible users that could benefit from the cradle.

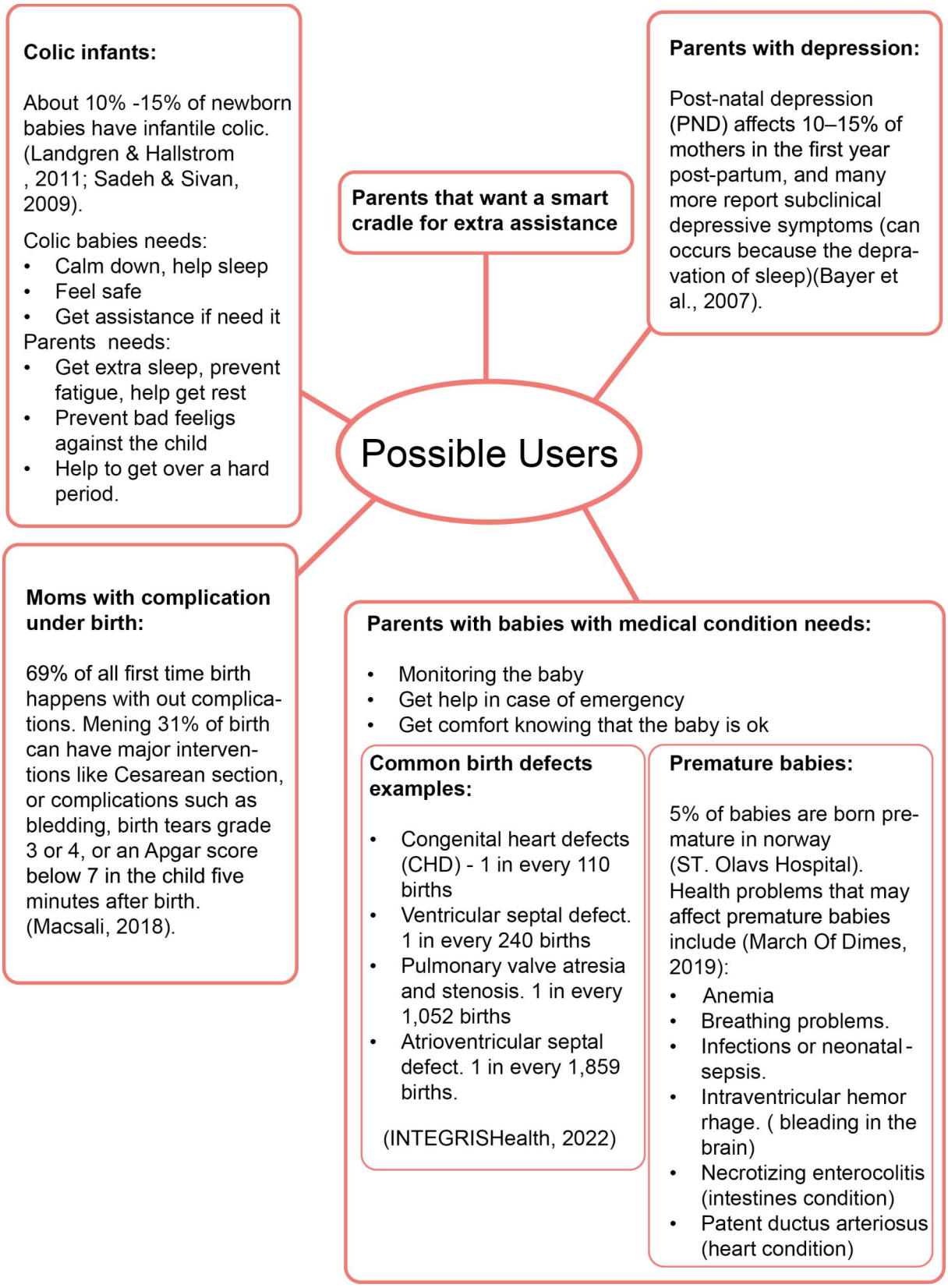



Figure 3: Possible user targets

## Creation of ideas:

To be able to start generating ideas I brainstorm using a SWOT matrix and a SCAMPER method(See appendix C).

**Idea:** Make a base cradle and a monitor module that can be connected as a service that is a medical device provided by the Municipalities.

**Base cradle idea:**

Could be enough for colic children and for parents that would like to purchase the cradle without costing too much.

**Functions ideas:**
- Rocking
- Can be locked (to be use as a normal cradle)
- Simple cry detection (Sound + movement) (low reliability and accuracy)
- Speaker

**App ideas:**
- Sound choice
- Motor on/off

**Monitor module idea:**
Is connected to the cradle to increase all the sleep tracking capabilities. Implementing the sonar gives the possibility of detecting if the baby is not breathing, or other abnormalities. The monitor is expensive but creates a high value for the users as it can be used for a much longer period of time for infants that may need it after the 6 months of age.

**Technology on the monitor ideas:**

- High reliability and accuracy of sleep detection and cry detection using a sonar.
- Room temperature and child temperature monitoring.
- Speaker.

**Monitor App ideas:**
- Warnings if crying do not stop, and need parental assistance (& warning that the baby needs to eat.)
- Alerts to the health system in case of an emergency situation.
- Choose sounds.
- Weaning mode for transition to crib.
- Adjust motion and sound.
- Needs to know the age of the baby.

**Ideas for algorithms that could be created:**
- Algorithm that detects when the baby is going to wake up and swing the cradle to try to make the baby sleep.
- Algorithms that change the speed and swing movements out of what the baby reacts best to.
- Algorithms that use sleeping patterns, respiration patterns and temperature to identify emergency situations.

**Idea for a service delivery channel:**

Health systems in municipalities can help to get medical aids from NAV's "hjelpemiddelsentralen", another way is that municipalities own aids that they can borrow away for a limited amount of time. This is the way the services of this product could work, the municipality could own an amount of these products and can be borrowed away. After birth, nurses follow the growing of the child and are the contact person for any help.

In case of colic, parents can get in contact with the nurses and borrow the medical aid for a couple of months and then return it back.
For newborn with medical conditions, premature childs, or mothers with complications under birth, could give the possibility for the parents to borrow this medical aid when they are sent home. This gives parents a way to monitor the condition of the baby as well to give them some extra hours of sleep or help mothers in the recovering phase.

Is important to not remove interaction with nurses and doctors. The aid is meant to support the work form the nurses and doctors and not take it away. The parents need to keep learning and get information about how to take care of the child. One important role of the nurses is to keep reminding parents that they are not failing as parents and the medical aid is to help sleep recover and to prevent psychological damage that could result in depression.

## Creation of possible scenarios incorporating these ideas:

**Scenario 1: Single mother**
She has had problems with the father of the child under pregnancy. This results in a difficult pregnancy with a cesarean section birth and a premature child. The mother is now a single mom with a premature child who is insecure and does not want to go home.
The doctors are sure that the mom and child can go home, but the mother is scared and worries about her baby's well-being. Doctors say that she has the requirements to get medical aid for a period of time that she can get by calling the medical center from the municipality she is assigned to. The mother feels more secure, but a good following of the child is still required.

**Scenario 2: Colic baby**
The baby has started crying for longer periods of time. The parent gets worried, maybe something is wrong with the baby? The baby has colic. The mom is at home with maternity leave, but the father is at work during the day and helps with the baby when he is home.
The parents start to get fatigated, they do not understand how a baby that is not sick can cry so much. They ask for help from the medical center when the baby has a development control and get tips and the possibility to get medical aid for a period of time. The parents can get some extra sleep and get through the difficult time easier.

**Scenario 3: Heart disease**
The baby was born with a heart disease. The doctors send them home when the baby is out of danger. The parents are very stressed out, they do not sleep well, knowing something can happen to the baby.
The parents start to get fatigated, they are always on alert. They get good help from doctors and nurses but could need more security at home. The medical center gives them the possibility to get medical aid for a period of time. The parents can get some extra sleep knowing that the baby is monitoring from home while they are sleeping.

## Product concept evaluations:

A set of product attributes was established, encompassing transportation and mobility, ergonomics, lightweight design, ease of cleaning, usability, sustainability, and aesthetics. That is later use in this thesis to compare designs. By using this approach, I ensured that the evaluation process considered the desired design criteria.

**1. Transportation and mobility:**

The service will not only deliver cradles to clients but also provide storage for them. This necessitates that the cradles are designed to occupy minimal storage space and are easily transportable to clients. It is crucial for clients to have the option to transport the cradles themselves. In the situations discussed earlier, parents often seek assistance from family members or close friends, resulting in frequent travel to different locations. Furthermore, mobility within the house is important as many parents move the cradle around to keep a close eye on their sleeping infants during the day.

**2. Ergonomics:**

Expanding on the previous point, the cradle's ergonomics play a crucial role in its movability. There should be strategically designed parts that facilitate a comfortable grip for moving the cradle. Additionally, the height of the cradle needs to be carefully considered to ensure that parents do not have to excessively bend over when placing the infant in the bed. To determine an optimal height, I conducted research on existing cradles and cribs available in the market. Based on my findings, a suitable height range for the cradle could be between 700mm and 800mm, with the bed positioned approximately 500mm to 600mm above the ground. This configuration will enhance usability and minimize strain on parents when using the cradle.

**3. Lightweight Design:**

The cradle should be designed to be lightweight, enabling effortless transportation and mobility. This consideration will influence the selection of materials and the dimensions of the cradle.

**4. Ease of Cleaning:**

Ensuring cleanliness and disinfection of the cradle when it is delivered to clients is essential for the service. Therefore, the cradle should be designed for easy cleaning, minimizing the use of resources.

**5. Usability:**

User-friendliness is a key aspect of the cradle's design. It should be easy to assemble, set up, and start using without any complications.

**6. Sustainability:**

The cradle should incorporate sustainable practices. This involves using eco-friendly and durable materials. The cradle should also be able to function as a bed even if the smart functionalities are not operational.

**7. Aesthetics:**

While the folding mechanisms give the cradle a "travel bed" appearance, elements of Scandinavian design should be implemented. This includes creating well-ventilated and airy spaces, incorporating tactile materials, and focusing on simplicity and functionality.

## Concept evaluations for Services:

**VitalThings:**

The concept idea was presented to the CTO of VitalThings through a presentation. After the presentation it was discussed that the product could be difficult to implement as a medical aid for ColiCot AS. To be a medical aid it needs to be developed again by an approved company such as VitalThings. For Colicot AS to get the certification the whole process of the development needs to be built around the certification. This process produces a report that contains all formal technical requirements and documentation requirements for the creation of a medical device. It is important to decide before the product is developed if the cradle will be developed for private use or medical use.

The most important is to define the purpose of the product. If the purpose is to prevent possible death of a baby and send a warning it becomes a medical aid and to prove that this function works a lot or resources and testing is needed. On the other hand if the purpose is only monitoring and will only send a data report to the parents or that can be readed from a professional, it is not a medical aid even if it is used as one. This shows the importance of the definition of the purpose for a product.

As a medical use the price for production and developing is not as important as meeting the requirements to get the medical certification. The price of medical aid can be very high and a number of international companies have shown interest in the radar technology used for the Somnofy, and have asked if the radar could be used for monitoring of children.

**Feedback from a nurse:**

An experienced health nurse, who has worked extensively with infants and sleep, was presented with the concept. She suggested using the cradle during the first 8 weeks during the day, and later on, during the night. She believes that such a cradle has potential and is open to this kind of product, provided that it is used correctly with the help of healthcare personnel. However, she noted that not all nurses share her view. She shared her experience with a family who bought a similar cradle (most likely the SNOO) which helped them a lot, but the price was very high.

**Feedback from Head of department a health clinic:**

She explains that they are working to reduce social inequalities, so advertising for an expensive cradle may become too commercial for the Municipality. They want to support parents to master, in relation to sleep, the “regular way”.

She does not think it is realistic to purchase the cradles at the health clinics. She does not have any decision-making authority, but maybe it could be discussed more internally. Another possibility could be using other platforms.

She believes that In a way, it would have been great if the health center could lend such a bed. Certainly good for some parents. But they are not in a position to vouch for maintenance, cleaning etc. A bed is an item of use, it gets worn out, and The National Association unexpected child death (“Landsforeningen uventet barnedød”, LUB ) thinks that mattresses should not be reused.

She notes that with approximately 2,000 children born in Trondheim municipality each year, prioritizing the use of the cradle could be challenging. The number of people in need of the cradle will be high, and the minimum loan period must be more than a week, as one week of good sleep is not enough. If the cradle proves to be effective, parents who use it for only a week will feel “pressured” to buy their own, which can be seen as marketing.

Furthermore, the cradle must be researched before any recommendation can be made. If

the cradle proves effective, the aid center or relevant associations and volunteer organizations could be the best way to acquire it. Social media, such as mommy blogs, could also be used to promote the cradle.

## Final learnings:

During the meeting with VitalThings, it was emphasized that defining the purpose of the product, especially when it is intended for the medical sector, is crucial. Implementing features such as alerting for unexpected child death or other medical conditions can be costly and resource-intensive. As a result, developing the cradle as a medical aid is not currently feasible for ColiCot AS.

From the discussion with the nurse, it was determined that the product would be most suitable for infants during the first 8 weeks during daytime and after 8 weeks during nighttime. It was also recognized that the product should work in collaboration with nurses to educate parents on promoting healthy sleep habits for their infants.

Based on input from the head department of a health clinic, it was deemed unrealistic for the municipality to own such a product. The challenges of prioritizing users, maintaining, and cleaning the cradles were cited as significant concerns. Furthermore, for the health clinic to endorse the cradle, further research is necessary to demonstrate its effectiveness. They are cautious about marketing the cradle and pressuring people to purchase it due to limitations on borrowing durations.

Using the feedback, it is intended to define the purpose of the product more. To achieve that two different directions were developed to compare and understand the direction of further development.

**Direction 1: Develop to be a medical aid**

- Definition of a medical aid: “The aids must be necessary and appropriate to improve the ability to solve practical problems in daily life, or to be able to be cared for at home.” (NHI, 2022)
- The data is used to trigger directly to another system or send a warning if it detects an abnormality on the baby.
- A certificate company needs to buy Colicot, and develop the product.
- VitalThings is a possibility because they already work with monitoring in the health sector and already have robust monitoring technology that can be expanded to the monitoring of babies.

**Direction 2: Develop to be a private product and service:**

- More traditional monitoring technology.
- The data is used to give information to the users, such as sleeping patterns and respiration patterns if possible.
- Can be bought, but it could also be used as an aid, if system like the aid center could use it.
- The need of a service to clean and maintain the cradles.
- Can be developed by a non-certificate company.
- Is easier to develop for Colicot AS.
- The price becomes very important to compete on the market.

**Common:**

- Needs to be safe.
- Movements of the cradle helps the baby to sleep - need to be proven. Example SNOO “Research has shown that babies who sleep in SNOO clock 1 to 2 more hours of sleep

each night than other babies...and many sleep 9 hours or more by 2 to 3 months old.”
- Test that the actuator works as it should.
- Development of the algorithms increases the value of the product.

For this thesis it will continue with the development of the cradle as a private product that can be bought or rented from the ColiCot company, with focus on the common points for both of the directions. Even if ColiCot was bought or chose to create the cradle as a medical aid, the common points need to be reached. Meaning that the first step is making a working prototype that can easily be tested and transported.

## 5.3 Final Concept version 2:

### 1. Product needs and specifications:

**Problem scenario:**

The users were reduced from the previous iteration to colic babies, parents with PND or risk of PND, mothers with complications under birth, and premature babies. To visualize this a persona and scenario was created.

**Name:** Anna Andersson
**Age:** 28

**Background:**

Anna Andersson is a 28-year-old woman who recently became a mother. She faced a difficult pregnancy due to problems with the father of her child, resulting in a premature birth via cesarean section. Anna lives approximately an hour away from her parents and frequently travels to visit them. The challenges of having a premature baby have resulted in sleep deprivation, making her even more tired and in need of rest and support.

**Personality:**

- Determined: Anna's determination to overcome the challenges she faces remains a significant aspect of her personality. She is motivated to find solutions and create a positive environment for herself and her child, despite her exhaustion.
- Vulnerable: Sleep deprivation and the demands of caring for a premature baby have made Anna more emotionally vulnerable. She may experience heightened stress and fatigue, requiring additional support to cope with her circumstances.
- Nurturing: Anna's love for her child is unwavering, and she strives to provide a nurturing and caring environment for her little one. She is constantly attentive to her baby's needs, even though her own need for rest is equally crucial.
- Sleep-deprived: The challenges of having a premature baby have resulted in severe sleep deprivation for Anna. She struggles to get adequate rest, which further adds to her exhaustion and affects her ability to carry out essential activities.
- Family-oriented: Anna greatly values the support and guidance of her parents. She seeks their assistance, particularly with the demands of caring for her premature baby, as they offer a reliable source of emotional and practical help.

**Goals:**

- Create a stable and loving environment for her child: Anna's primary goal is to establish a secure and nurturing home environment for her premature baby. She wants to provide the best possible care, despite her own exhaustion.
- Prioritize self-care and rest: Anna understands the importance of taking care of herself to be an effective caregiver. She aims to find ways to prioritize rest and rejuvenation, seeking help and resources that allow her to get the sleep she desperately needs.

**Challenges:**

- Severe sleep deprivation: The challenges of having a premature baby have significantly disrupted Anna's sleep patterns. The resulting exhaustion can impact her physical and emotional well-being, making it difficult to perform daily tasks.
- Emotional vulnerability: Sleep deprivation can intensify emotional vulnerability. Anna may experience heightened mood swings, frustration, and feelings of overwhelm. She requires additional support and understanding during this challenging time.
- Limited time and energy: With her need for sleep and the demands of caring for a premature baby, Anna may struggle to find time for personal activities and self-care. Managing her limited time and energy becomes crucial for maintaining her well-being.

**Functionality:**

These functions of the cradle work together to create a soothing and supportive sleep environment for the baby, while also providing parents with valuable information and assistance in understanding their baby's sleep patterns. The product is intended to be used on full capability by connecting the cradle and monitor module together.

- Rocking function:

Manual Mode: The cradle allows manual rocking with adjustable intensity and duration. It can be set using a timer during the daytime, providing a gentle motion to soothe and comfort the baby.

Night Mode: The cradle offers a special nighttime setting that aims to help the baby sleep better during the night. The rocking motion in this mode is optimized to promote a more peaceful and longer sleep.

Figure 4: App Sign in

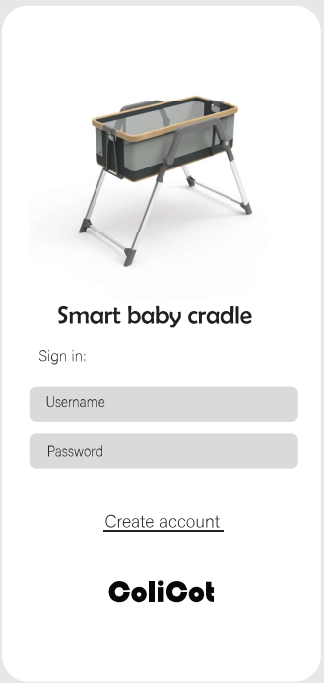
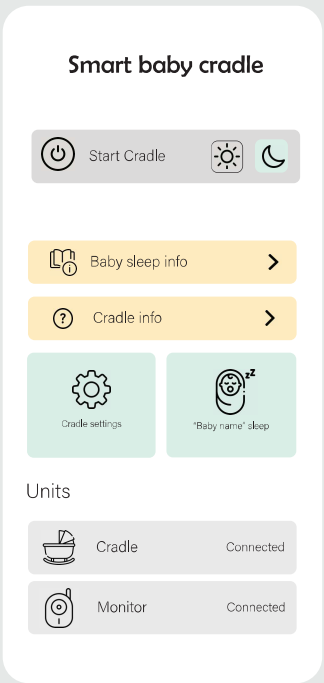



Figure 5: Main Screen




- Sleep Detection and Cry Detection:

Sleep Detection: The cradle utilizes a microphone and speaker system, acting as a sonar, to track the baby's sleep patterns. It detects when the baby falls asleep, wakes up, or transitions between sleep stages.
Cry Detection: The cradle's microphone picks up the baby's cries and triggers appropriate responses, such as activating the rocking motion or playing soothing sounds to help calm the baby.

- App with Useful Information:

Usage Guide: The cradle's app contains detailed instructions on how to set up and use the cradle effectively, ensuring the baby's safety and comfort.
Baby Sleep Information: The app provides helpful resources and information on topics such as baby sleep, colic, and seeking assistance, aiming to educate parents and support them in understanding their baby's sleep needs.

- Auto Mode:

Automatic Rocking: The cradle includes an auto mode that detects when the baby is awake or needs soothing. It triggers the rocking motion automatically to help lull the baby back to sleep without requiring manual intervention.

- Weaning Mode:

Transition Assistance: The cradle includes a weaning mode designed to help transition the baby from the cradle to a crib gradually. Over time, the cradle reduces the number of times the rocking motion is activated until it eventually ceases, allowing the baby to adapt to sleeping without the cradle's movement.

Figure 6: Change settings

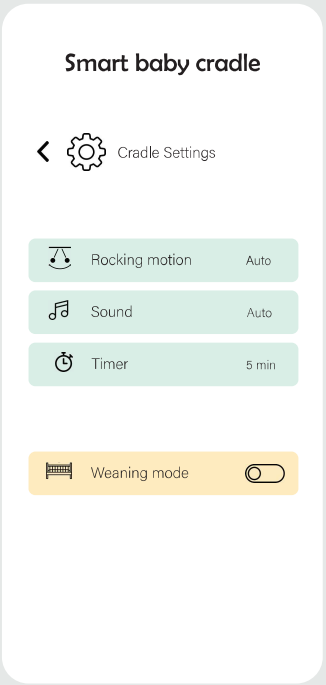
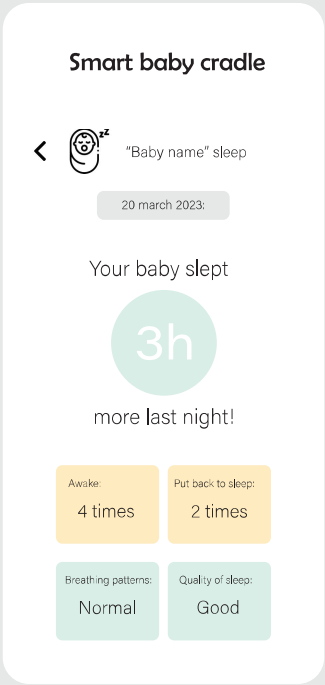



Figure 7: Find extra sleep info




- Sound Options:

Sound Selection: The cradle provides various sound options such as white noise, heartbeat sounds, and possibly more. Parents can choose the sound that works best for their baby's comfort and sleep.

Volume Control: The cradle allows adjusting the volume of the selected sound to a suitable level that provides a soothing environment for the baby.

- Sleep Report:

Daily Report: The cradle's app sends a report every morning to provide parents with essential information about their baby's sleep. The report includes details such as sleep quality, the number of awakenings, the effectiveness of the cradle in inducing sleep, and potentially breathing patterns if detected.

**Technology:**

Understanding the how the cradle works:

Colicot owns the patent for the Virtual Adjustable Pivot Axis (VAPA), which was created by Terje Rølvåg. This patented mechanism allows for customized cradle motion. The invention is based on one or two flexible 2D structures that enable two translational movements and a flexible tilting rotation about a virtual pivot axis, resulting in three degrees of freedom (DOF's). The direction of the pivot axis is determined by either the two pivot points or the surface normal of the flexible structures. Additionally, the center of rotation is determined by the geometry and can be located outside the volume of the flexible structure itself. (See appendix B)

After examining previous designs and prototypes of this cradle, it was discovered that the VAPA mechanism could be customized using straps instead of one flexible structure while still achieving the desired results. One of the advantages of using straps is that they create space between the structure and the cot, reducing the risk of clamping. The current prototype is constructed out of wood and is relatively heavy for a cradle. The actuator is located beneath the cot and is powered by a 24V power supply. The cradle is designed to connect to a phone and activate when the baby cries. This is detected on the microphone of the phone. While the cradle has received positive feedback from previous tests, it does have issues with size, weight, and transportation. As found in the section reviewing older master thesis.

Algorithm:

- Sleep Tracking: The cradle's algorithm analyzes data from the microphone and speaker system to track the baby's sleep patterns, including sleep onset, duration, and transitions between sleep stages.
- Breathing Pattern Monitoring: The algorithm also processes data from the microphone and speaker to monitor the baby's breathing patterns and ensure their safety.
- Sleep Report Generation: Based on the collected data, the algorithm generates a sleep report that provides insights into the baby's sleep quality, awakenings, and breathing patterns if detected.

## Sketches

Before sketching, a mood board was developed (see Appendix D). Additionally, as discussed in the product concept evaluation section, a set of product attributes was established, encompassing transportation and mobility, ergonomics, lightweight design, ease of cleaning, usability, sustainability, and aesthetics.

The sketches were developed while keeping these key points in mind.I generated multiple sketches exploring different solutions of different forms. Among these sketches, several exhibited similarities, prompting me to narrow down the options to three distinct base forms, shown on figure 8, from which new designs could be derived. Subsequently, I carefully assessed each of the three base forms in relation to the aforementioned points, as shown on Table 3, aiming to identify the one that displayed the greatest potential. By using this approach, I ensured that the evaluation process considered the desired design criteria, leading to the selection of the base form with the highest perceived potential, base form 1. The base form 1 was used to create more refined concepts: concept 1 (figure 9) concept 2 (figure 10), and concept 3 (Figure 11).

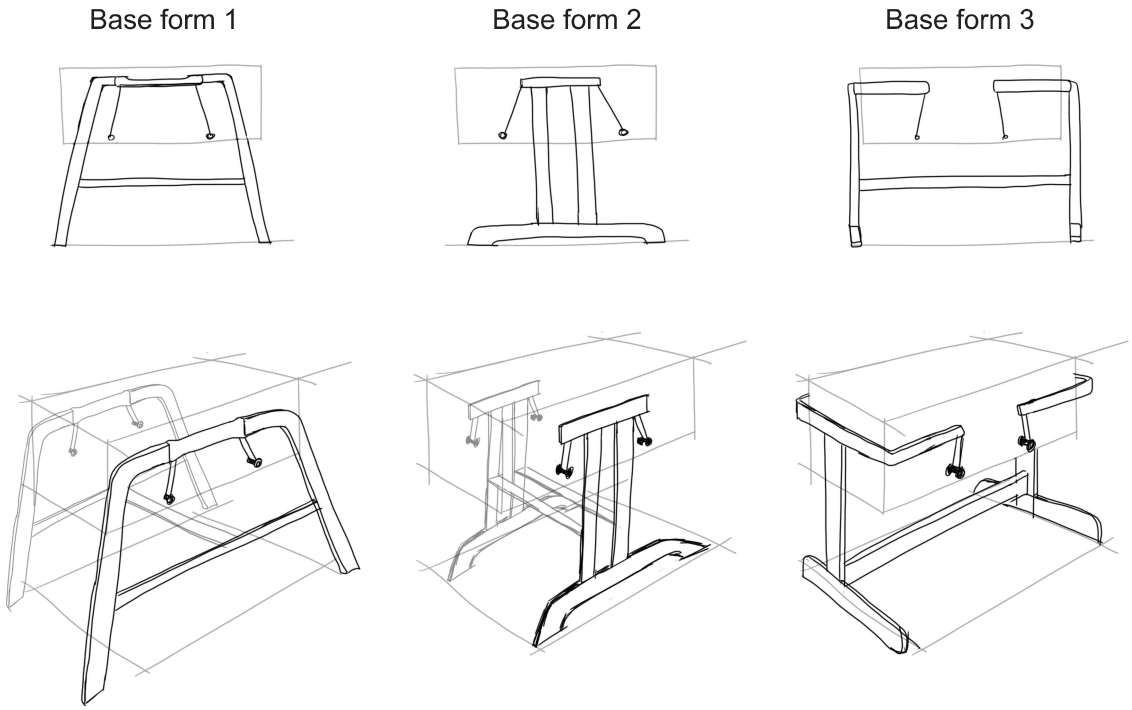



Figure 8: Base form from where the new concept was derived

Table 3: Comparison of base forms against product attributes

| | Base form 1 | Base form 2 | Base form 3 |
|---|---|---|---|
| Transportation and mobility | • Use more space | • Challenging to make a folding mechanism. | • Challenging to make a folding mechanism. |
| Ergonomics | • Easy to make natural handles and grip points. | • Easy to make one specific grip points. | • Challenging to make good grip point |
| Lightweight Design | • Give flexibility for materials. | • Give flexibility for materials. | • Most posible needs to be made of metal. |
| Ease of Cleaning | • There will have a detachable cot. | • There will have a detachable cot. | • There will have a detachable cot. |
| Usability | • Dependent of the folding mechanism | • Dependent of the folding mechanism<br>• Stability can be a issue. | • Dependent of the folding mechanism |
| Sustainability | • Give flexibility for materials.<br>• Can be use without iot capabilities. | • Give flexibility for materials.<br>• Can be use without iot capabilities. | • Most posible needs to be made of metal.<br>• Can be use without iot capabilities. |
| Aesthetics | • Easy to test multiple forms | • Not to easy to test multiple forms. | • Not to challenging to test multiple forms. |

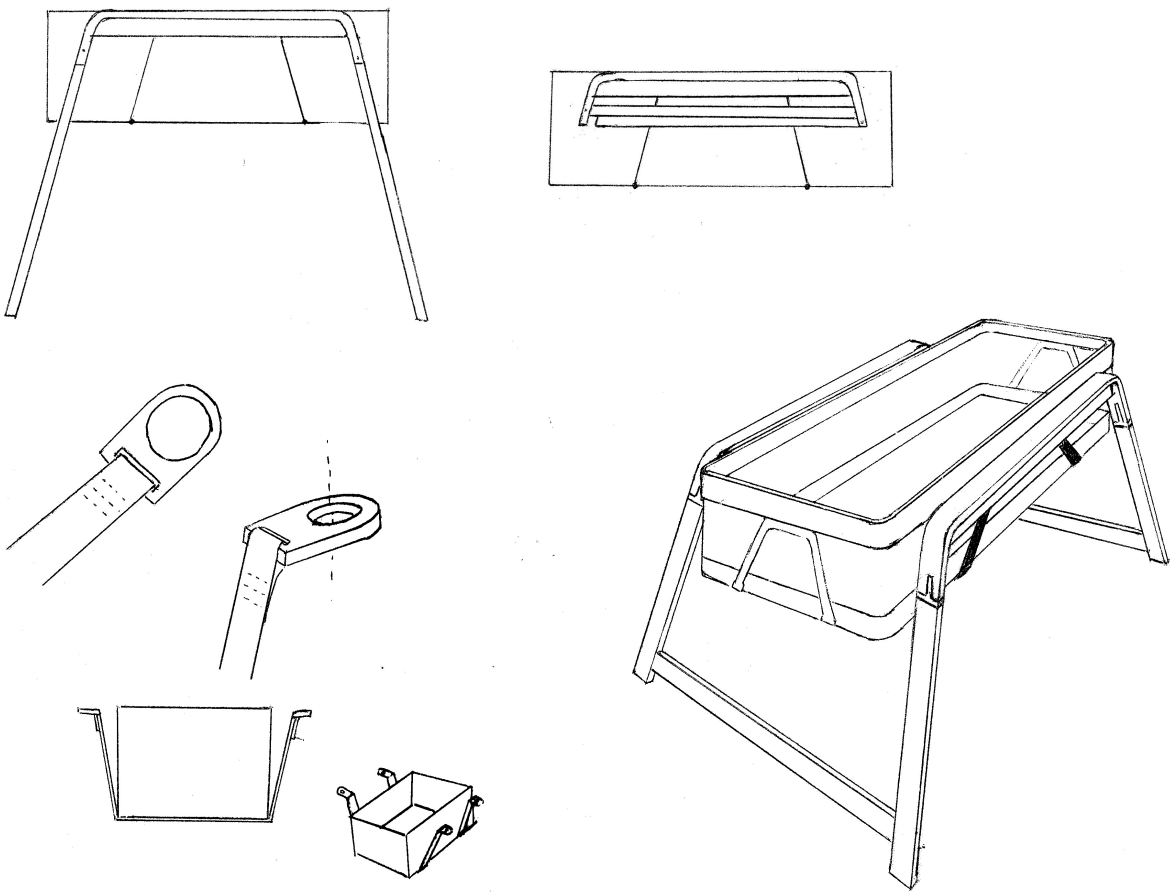


Figure 9: Concept 1

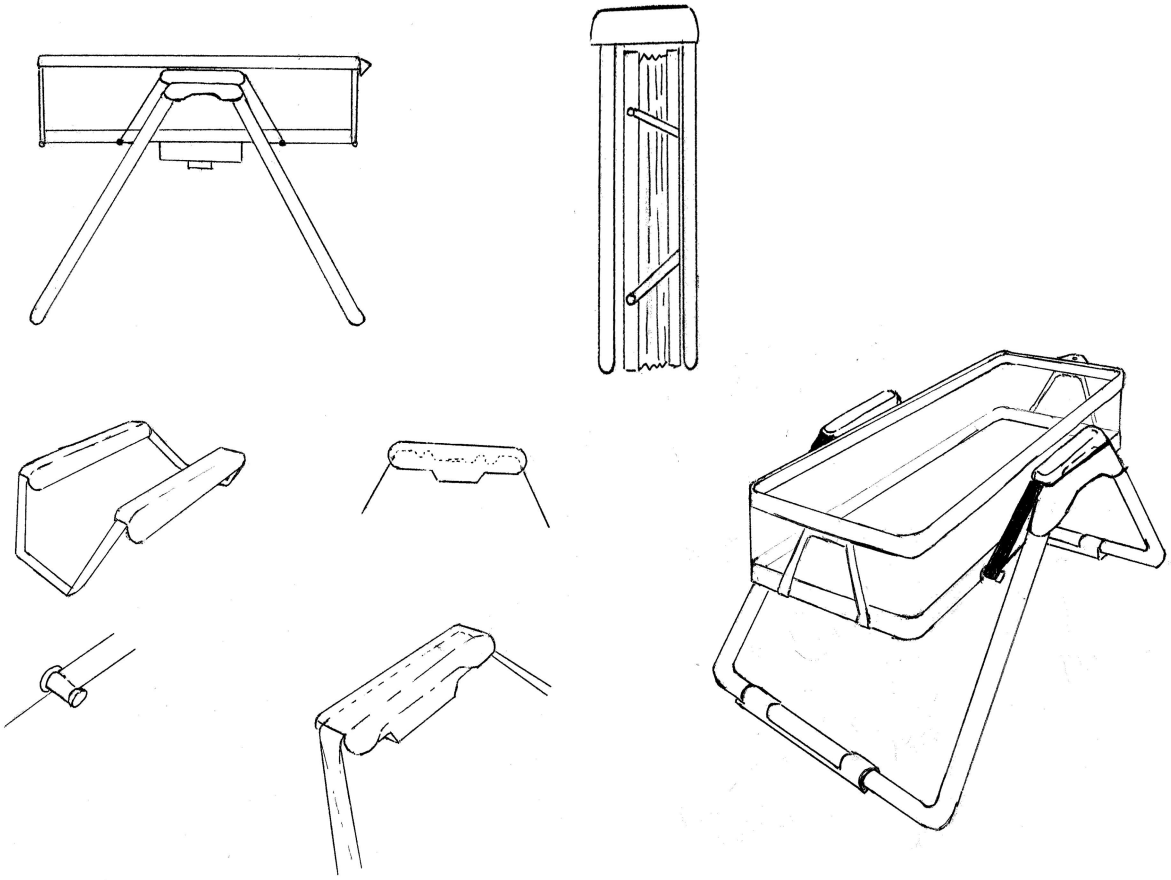


Figure 10: Concept 2

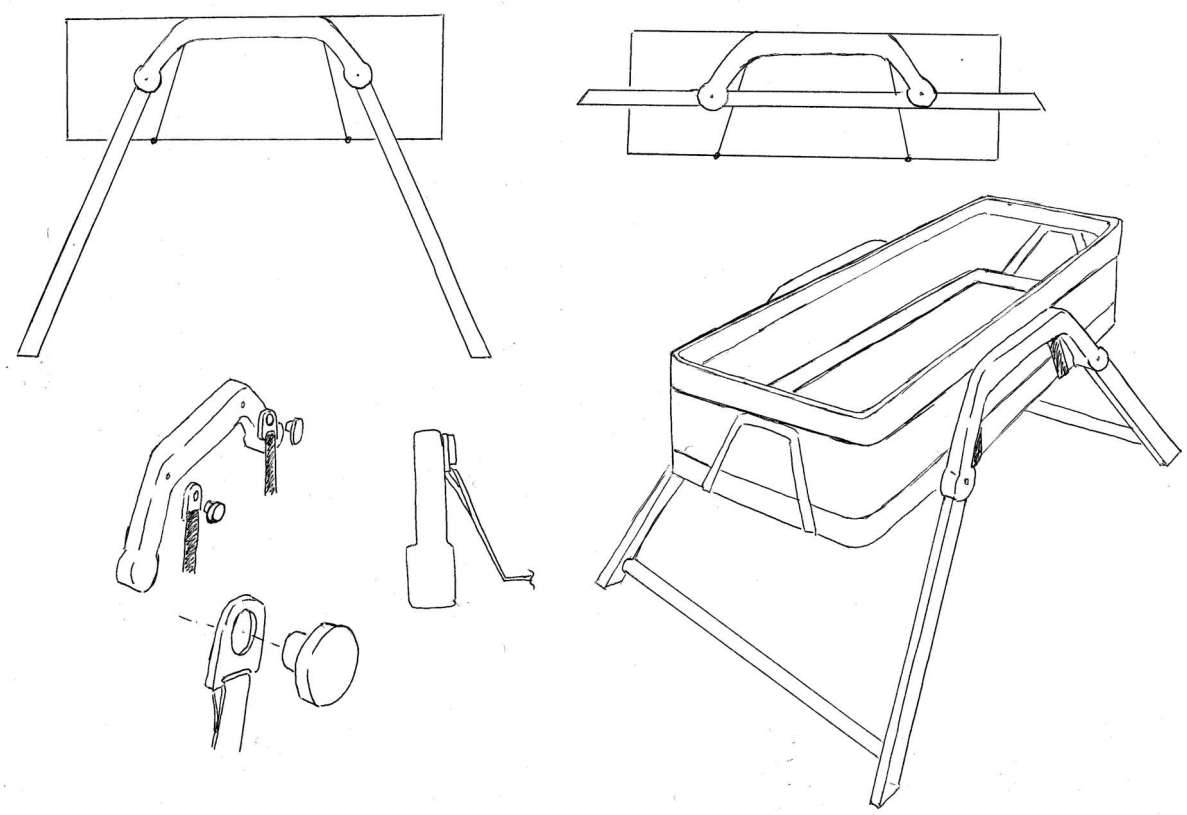


Figure 11: Concept 3

To evaluate the designs and determine the most suitable one for the intended context, the same matrix (table 4) with the product attributes was used. Each concept was assessed and compared based on how well it aligned with these attributes. As previously discussed,the utilization of this matrix enabled the identification of the design with the highest potential to meet the specific requirements and demands of its intended use context. The result was the selection of concept 3 for further development, as it shows to be the most balanced and versatile of the three concepts.

Table 4: Comparison of concepts against product attributes

| | Concept 1 | Concept 2 | Concept 3 |
|---|---|---|---|
| Transportation and mobility | • Very space efficient<br>• Decent folding mechanism. | • Difficulty in attaching the cot and the legs together when both are in a folded position. | • Litte longer that the others concepts.<br>• Balanse between lengh and height |
| Ergonomics | • The sides of the structur provide a natural grip. | • The grip is combined with the locking mechanism. | • The sides of the structur provide a natural and good grip. |
| Lightweight Design | • Heaviest | • Lightest | • Balanced |
| Ease of Cleaning | • There will have a detachable cot that will be easy to clean. | • There will have a detachable cot that will be easy to clean. | • There will have a detachable cot that will be easy to clean. |
| Usability | • Dificult to make it the rigth height without expanding the top part.<br>• Stable design | • Need extra steps for deassambling<br>• Can have stability problems | • Can have good noticeable buttons for the locking mechanisms.<br>• Good stability |
| Sustainability | • Top part of the frame is made of hardplastic<br>• Leggs can be made of wood, aluminium or steel.<br>• Durable design. | • Steel or aluminium legs<br>• Multiple parts of hardplastic<br>• Durable design. | • Top part of the frame is made of hardplastic<br>• Leggs can be made of wood, aluminium or steel.<br>• Durable design. |
| Aesthetics | • Sensations of a walker by using metal legs.<br>• Simple design.<br>• Funcional but simple design | • Metal tubes gives a cheap feeling. | • Balance contrast of materials.<br>• Funcional but simple design |

For the evaluation of the cot, a new set of design attributes were created. Three design attributes were taken into consideration: breathability, durability, and visibility.

1. Breathability: The cot must have good airflow to ensure proper ventilation for the infant. This is crucial for maintaining a comfortable and safe sleeping environment.

2. Durability: Since the cot will be subjected to frequent washing, it needs to be durable enough to withstand regular cleaning. It is important to note that the mesh part of the cot may be less durable compared to the cloth part. Finding a balance between breathability and durability is essential.

3. Visibility: Parents prioritize having good visibility of their infant while they are in the cot. This allows them to easily monitor their child's well-being and provides peace of mind.

By evaluating the sketches on table 5, I concluded that the cot design 2 is the better choice. The cot is meant to be assembled on a structure that has a folding mechanism as shown in Figure 13.

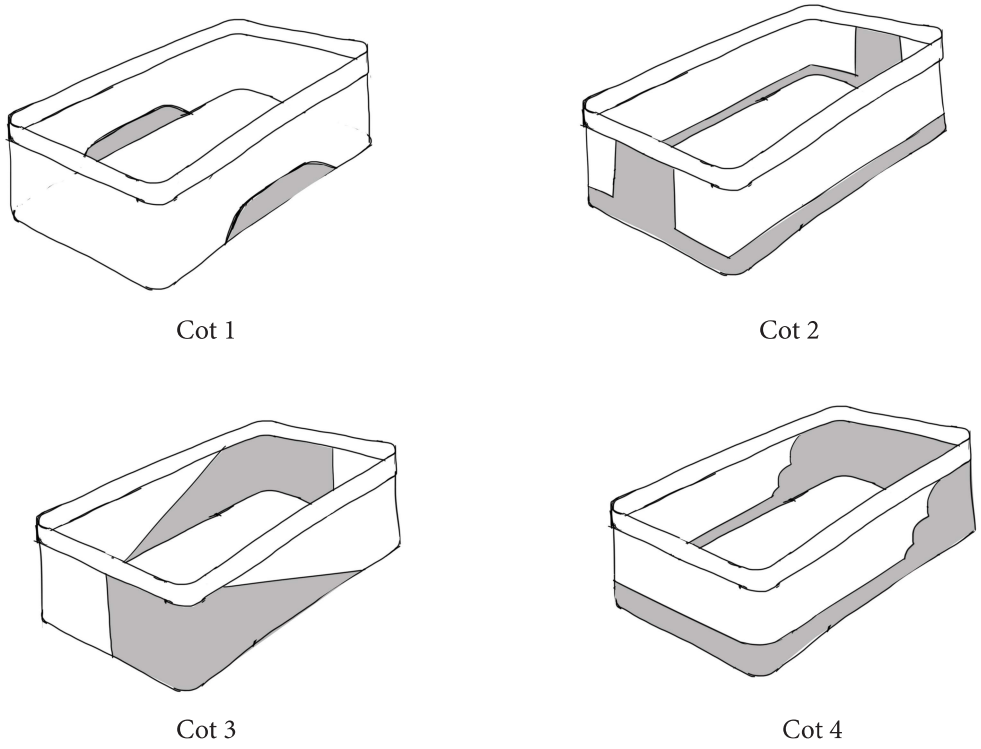



Figure 12: Cot concepts

Table 5: Comparison of cot concepts against product attributes

| | Cot 1 | Cot 2 | Cot 3 | Cot 4 |
|---|---|---|---|---|
| Breathability | High | High | Medium | Medium |
| Durability | Low | High | Medium | High |
| Visibility | High | High | Low | Medium |

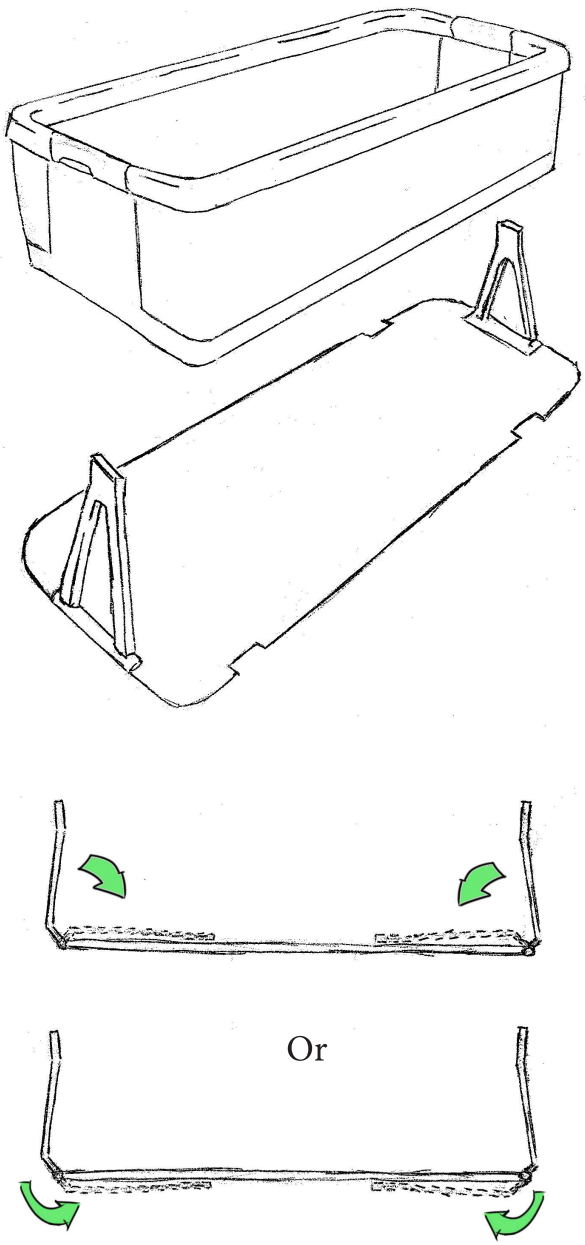



Figure 13: Cot structure

## Functional Prototype:

### Components:

Actuator Possibilities:
The prototype cradle uses a maxon EC 60Ø 100w brushless motor at 24v, that moves a weight around its center, creating the movement of the cradle. The speed of the motor needs to match the geometry of the VAPA structure creating oscillation. From the literature it is shown that frequencies between 1 hz and 1.5 hz have a soothing effect on the baby. Meaning that the motor needs to rotate 1 revolution per second (9.552 rpm) to create an oscillation of 1 hz.

### Actuator choice:

Different kinds of motors were taken under consideration. Is important that the motor produce low noise, have enough torque to rotate the weight, and have a relatively small size.
For the thesis I have chosen to use the stepper motor with a combination of a noise reduction controller (TMC2209 stepper motor driver), mainly because of the price and time needed to set up. With more time the better choice is the implementation of a brushless motor with an ESC (electronic speed controller) or a FOC (Field orientation controller). The use of a brushless motor should decrease noise and the size of the actuator.

### Stepper Motor & TMC2209:

The stepper motor is a Nema17 Motor with a rated current of 1.5 A per phase and a holding torque of 420 mNm. To be able to control a stepper motor controller is needed. The TMC2209 was used because of the reduction noise capabilities. A drawback of using this for the prototype is the size. As shown in figure x the motor is outside the actuator enclosure. This is not optimal for the production of the final product.

A normal stepper motor has 200 full steps per revolution of the motor shaft. The TMC2209 The TMC2209 supports microstepping, which enables the motor to move in smaller increments than the basic step angle. This results in smoother and more precise movement (Trinamic, 2019).

The code (figure 16) and connection diagram (figure 15)for the prototype is very simple and uses the accelstepper library. This example code rotates the motor on 1 rps when on.

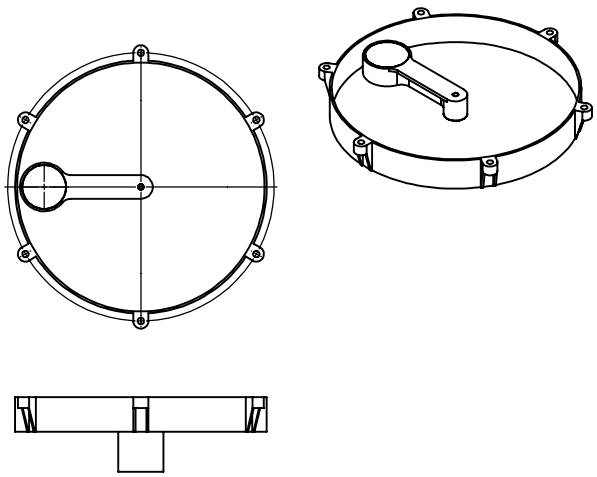


Figure 14: Actuator for stepper motor

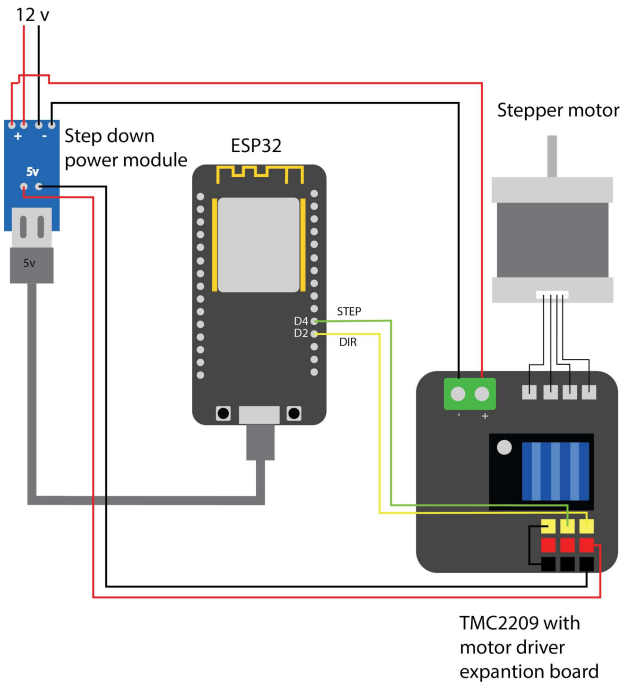



Figure 15: Connection diagram for stepper motor

```ino
#include <AccelStepper.h>

#define MAX_POSITION 0x7FFFFFFF // maximum of position we can set (long type)
const int dirPin = 2;
const int stepPin = 4;

AccelStepper stepper(AccelStepper::DRIVER, stepPin, dirPin);

void setup() {
  Serial.begin(9600);

  stepper.setMaxSpeed(1600);   // set the maximum speed
  stepper.setAcceleration(400); // set acceleration
  stepper.setSpeed(200);         // set initial speed
  stepper.setCurrentPosition(0); // set position
  stepper.moveTo(MAX_POSITION);
}

void loop() {
   if (stepper.distanceToGo() == 0) { // if motor moved to the maximum position
    stepper.moveTo(MAX_POSITION);       // move the motor to maximum position again
    }
    stepper.run(); //Move motor

}
```

Figure 16: Example code for stepper motor

**Brushless motor and motor controller driver:**

The use of a brushless motor is more expensive and not as straightforward to set up as the stepper motor, but brushless motors can run very quietly, and can produce more power for their size and weight. This makes the overall size of the actuator smaller and can everything be put together in one enclosure as shown on Figure 17. It was found that the brushless motors are typically controlled by an ESC or a FOC motor controller as mentioned before. For this product a FOC control will be cheaper and can be programmed with the help of the SimpleFOC library in arduino. The FOC control is perfect to control the motor at lower speeds with high torque. To optimize the performance of a motor, it is important to choose a motor with appropriate characteristics for the intended application. The internal resistance of the motor needs to be high (higher than 10 ohm), to create smooth performance at low speeds. It was found that Gimbal motors can be perfect for this kind of application. I recommended to use is the Gimbal GBM 5010 - 150T (Figure 18), with an internal resistance of 14.65ohms.

Using a FOC motor controller typically needs a position sensor to read the position of the motor pretty similar to a servo motor. For this product the motor only needs to move at a constant speed, this means that we can use a velocity open-control loop control. This allows it to run on a desired velocity without using a position sensor such as encoders or hall sensors. An open-loop control system relies on a pre-calculated voltage or pulse-width modulation (PWM) signal to be applied to the motor based on the desired speed (SimpleFOC, 2021).

The control signal is typically determined by the motor controller based on the motor's specifications, such as its rated voltage, current, and speed. However, open-loop control may not be as precise as closed-loop control methods that use feedback sensors. Since there is no feedback position loop to adjust the signal based on the motor's actual speed.

The SimpleFOC library includes a velocity open-loop control by specifying the limit voltage or limit current. It uses an algorithm where users can set the target velocity it wants to achieve, then the algorithm finds out what is the next angle needed to be setting the voltage to the voltage limit in that direction and applying a PWM signal (SimpleFOC, 2021).

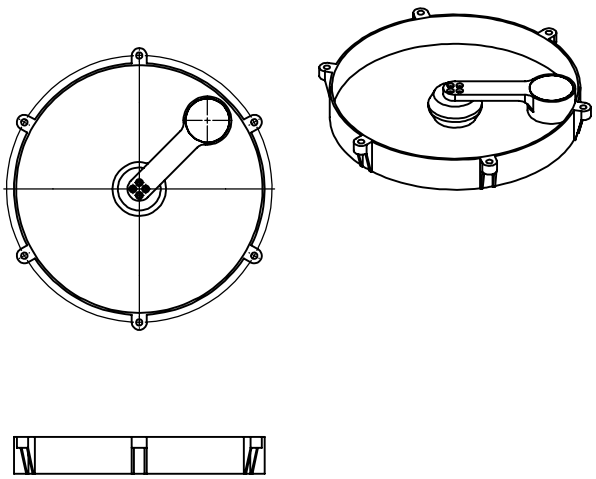


Figure 17: Actuator for brusless motor


Figure 18: Brusless motor GBM 5010 - 150T

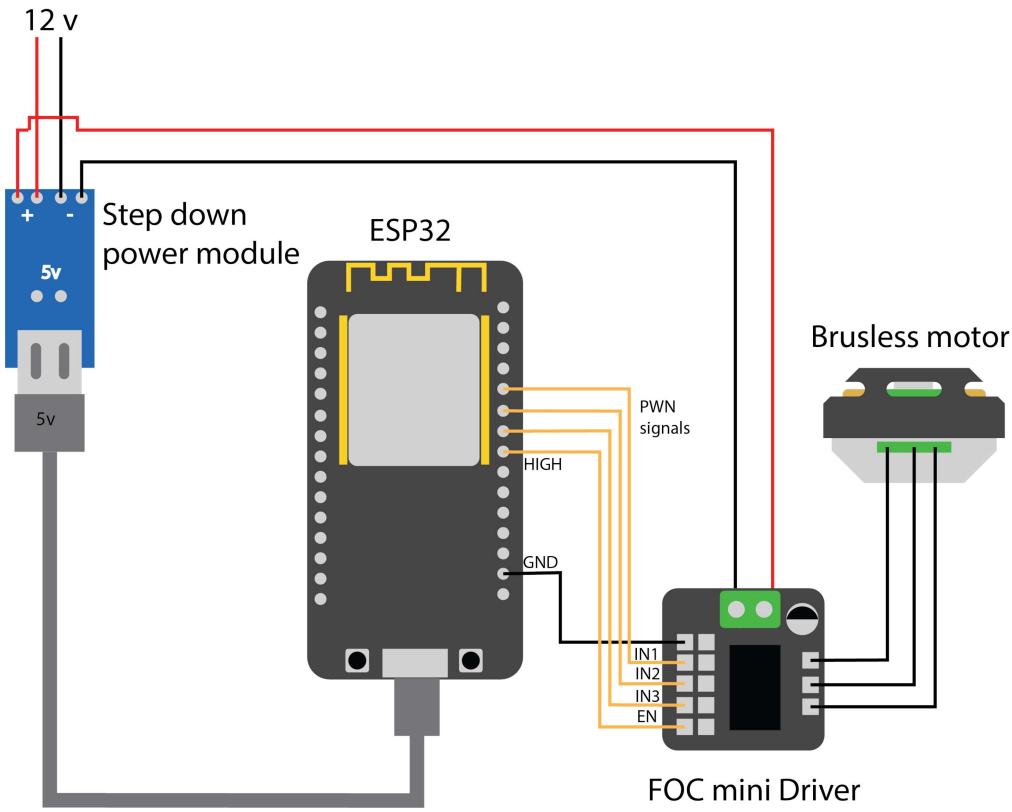



Figure 19: Connection diagram for brusless motor

**Materials and choices for prototyping:**

For the development of the cradle, several key design decisions were made. One notable decision was to simplify all the locking mechanisms to a simple joint rotation. These components hold significant importance in the overall design and need more in depth development to improve their strength, durability, reliability, and usability.

In order to simulate the desired characteristics of the final product, different materials were used for specific elements. To create the prototype, 3D printed parts were made using PLA with a 30% fill. This choice allowed for rapid prototyping and efficient evaluation of the design. During the initial stages of prototyping, wooden legs were employed. This material was readily available in the workshop and offered ease of manipulation, enabling the creation of a functional prototype within a short timeframe.

One iteration of the cot utilized paper to represent the cloth, while plastic was employed to simulate the mesh. However, future iterations are planned to incorporate actual cloth and mesh materials..

When it comes to the type of straps used. These straps, commonly used for securing objects on cars and trailers, were chosen for their high strength and weight-bearing capacity.

**Deliberations:**

During the development process, a few challenges and limitations arose, impacting certain aspects of the cradle design. Here are the details:

1. Printing and Reinforcements:

Printing the entire part as a single piece proved to be impractical, necessitating the division and subsequent gluing of parts together. Unfortunately, this approach created weak points, leading to breakage. To address this issue, rein-

Figure 20: Building of the prtotype

Figure 21: Prtotype fold

forcements were created using steel, providing additional strength. In hindsight, a potentially better solution could have been laser cutting acrylic parts lengthwise and then assembling them with glue, which could have resulted in a stronger representation of the part's structural integrity.

2. Additional Strap for Stability:

The 3D printed parts used for the joints did not possess sufficient strength, requiring the inclusion of an extra strap beneath the cot to enhance stability. This addition proved to be highly effective in reinforcing the structure and ensuring stability.

3. Brushless Motor Implementation:

In this particular prototype, it was not possible to implement the desired brushless motor design. The focus shifted towards using a stepper motor to create the necessary movements for the cradle. Consequently, the implementation of the brushless motor became a lower priority. However, a connection diagram was created, and the required parts were identified to be able to implement it in the future.

4. Limitations on Minimum Functionality:

Due to time constraints, it was not possible to incorporate the minimum functionality intended for testing. Specifically, the implementation of sound and a microphone had to be postponed. While these features were initially planned, the limited timeframe prevented their inclusion in the current prototype.

Figure 22: Prtotype on user context (bedroom)

Figure 23: Prtotype on user context (livingroom)

## Final Design:

The concept 3 was developed further using CAD software and resulted in the creation of a physical prototype. The design consists of a base structure that allows for the connection of the cot as shown on Figure 28. To ensure safety and compliance with the ASTM F2194 standard, a 2-step locking mechanism is implemented on each side of the connection between the cot and the structure. Additionally, this 2-step locking mechanism is utilized for folding the legs, enhancing the overall safety of the cradle (Figure 27).

The cradle itself is part of a larger product that includes a monitor. This monitor can be attached to the cradle, providing advanced sleep tracking and breathing monitoring capabilities (Figure 26). Even as the baby outgrows the cradle, the monitor remains functional, making it highly valuable for parents of premature infants or children who require extra monitoring. When both the cradle and the monitor are connected, the cradle can detect when the infant is about to wake up and assist in putting them back to sleep. The specific functions of the cradle are discussed in more detail in the functionality section.

Figure 24: Concept render 1

Figure 25: Concept render 2

Figure 26: Monitor connection and button details

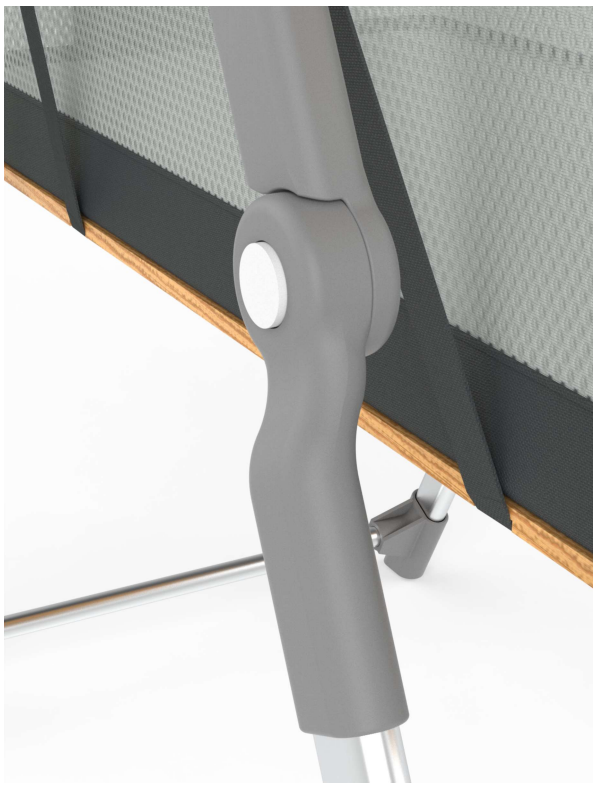


Figure 27: Rotation and locking mechanism

Figure 28: Cradle assambly

Figure 29: Strap attachment

Figure 30: Product render

## Size specifications:

The dimensions of the cot were determined based on standard measurements commonly used for mattresses sold by retailers specializing in children's and baby accessories. The height of the cot was carefully considered to strike a balance between safety and avoiding excessive size. For determining the frame dimensions, the goal was to achieve a balance between stability, efficient material utilization, weight, height, and the compactness of the folded product. Multiple iteration with a Cad software was made to ensure that the folding mechanism and the overall volume use of the cradle was functional and met the requirements.

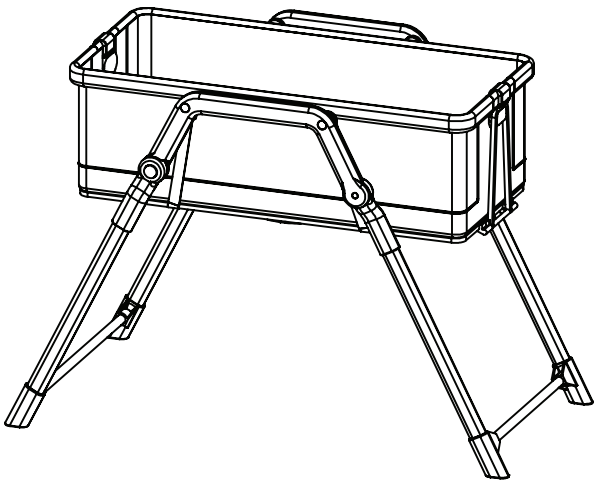


Figure 31: Cradle unfold

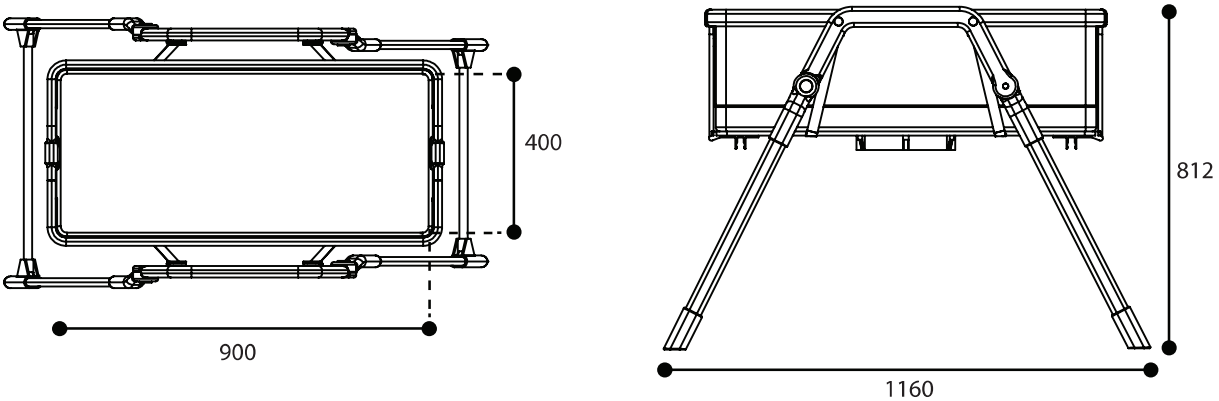



Figure 32: General dimentions unfold

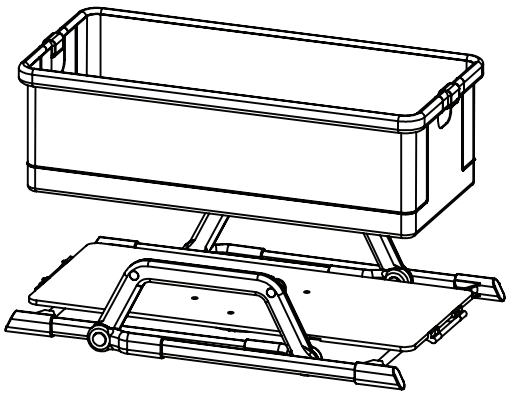


Figure 33: Cradle fold

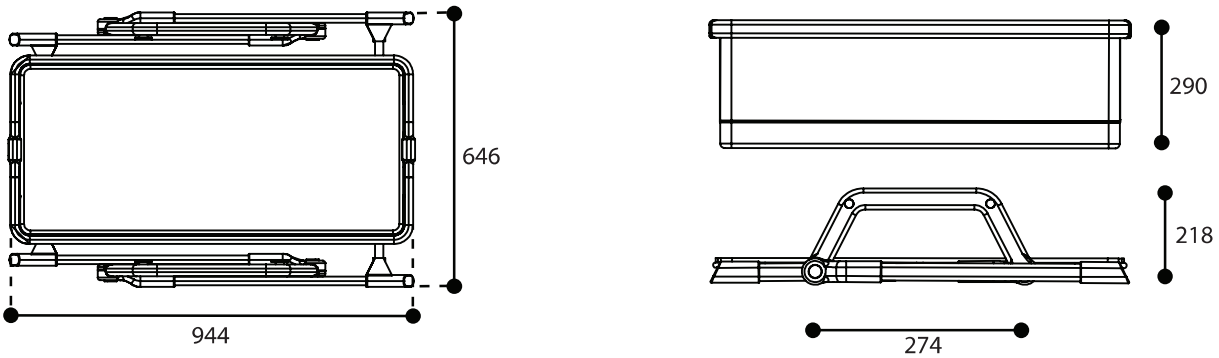



Figure 34: General dimentions fold

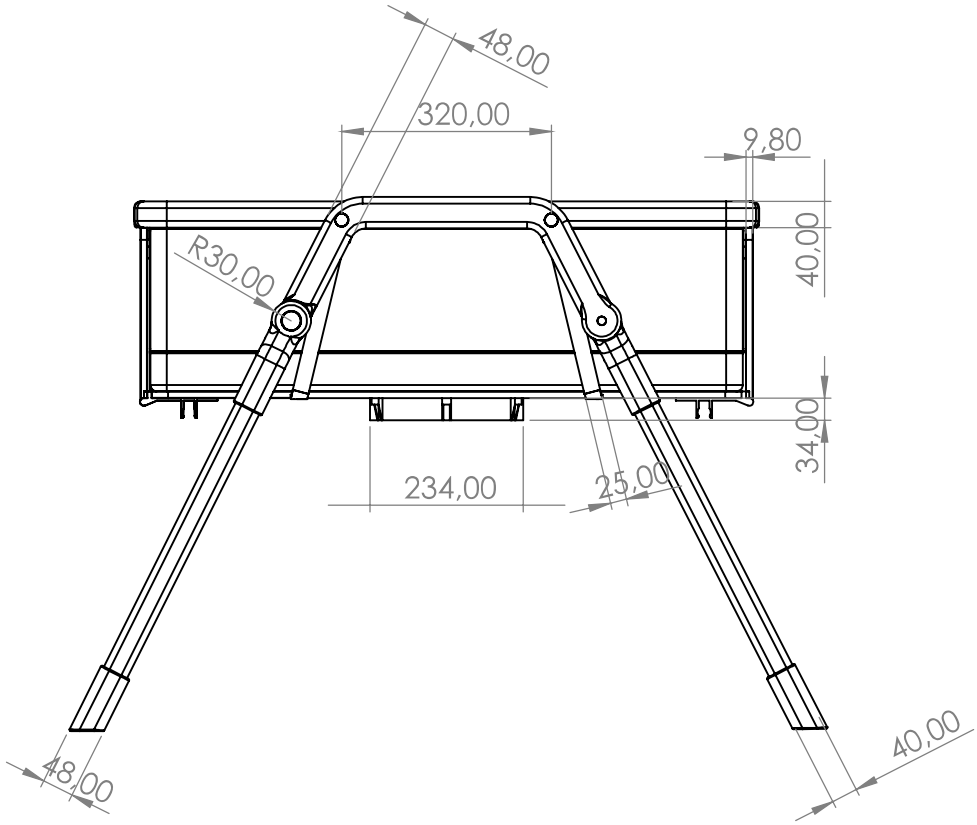



Figure 34: Detail dimentions 1

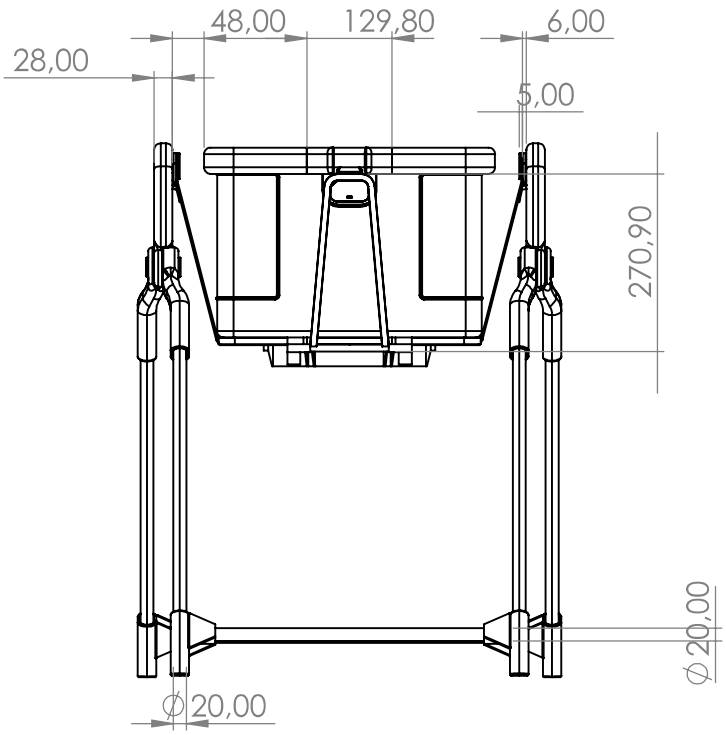



Figure 35: Detail dimentions 2

## Final Material:

One important material used for the cot is a polyester mesh. This mesh material has several benefits. It allows for a semi-transparent effect, allowing parents to see their baby inside the cot. It also promotes breathability, ensuring good air circulation for the baby's comfort. Additionally, the mesh has low elasticity, providing a protective barrier for the baby. It is comfortable and soft to the touch and can be easily cleaned by putting it in the washer. Many other cradle competitors also use this material. The cloth used for the cot needs to be durable and hypoallergenic, ensuring the baby's safety and comfort.

When determining the materials for the frame and structure parts, I used the attribute matrix to ensure that the design met the required criteria, and compared the materials as shown on Table 6. I chose to use plastic and aluminum as the main materials for the frame. Plastic is a versatile material that allows for easy design of

Table 6: Comparison of materials against product attributes

| | Aluminium | Steel | Wood | Plastic |
|---|---|---|---|---|
| Transportation and mobility | • Sturdy and durable | • Sturdy and durable | • Can more easily be scrached or can broke | • Make asambly and modularity easier<br>• Flexibility make plastic able to handle damage |
| Ergonomics | • Cold to the touch | • Cold to the touch | • Warm for the touch | • Easy to make form for handles and locking mechanisms |
| Lightweight Design | • Ligth weigth and sturdy | • Heaviest | • Ligth weigth but do not last that long. | • Is long lasting |
| Ease of Cleaning | • Resistant to corrosion | • Need to be protected to corrosion | • Need to be protected with a finish | • Do not have corrosion |
| Usability | • Strong, do not need to be to becarefull | • Strong, do not need to be to becarefull | • It bend more | • Clams, lock mechm. |
| Sustainability | • Non toxic material<br>• Strong and long lasting<br>• Can be recycled | • Strong and long lasting<br>• Need non-toxic finish<br>• Can be recycled | • Need non-toxic finish<br>• Not to easy to be recycled | • Needs to be non toxic<br>• Can be recycled |
| Aesthetics | • Do not need special coating finish | • Different finish and colors | • Retain value<br>• Warm feeling<br>• Coating | • Contrast to the other materials<br>• can have diferents finish |

connections, snaps, and locking mechanisms with high accuracy. Aluminum, on the other hand, is durable and sturdy, requiring no additional coating or protection against corrosion.

Some wood was incorporated into the frame for the cot. Wood was selected because it provides a pleasant tactile experience. This part of the frame can be used to manually rock the cradle. Wood also adds a natural warmth to the overall design, creating a cozy and welcoming atmosphere. The warm tones and organic textures of wood contrast with the more functional aspects of the frame's complex form and style.


Figure 36: Final materials for the product

## Use case scenario:

**Scenario: Anna's Journey with the Baby Cradle**

Background:

**Anna Andersson** is a 28-year-old new mother, and her baby is less than 8 weeks old. The sleepless nights and constant need for closeness have left Anna feeling exhausted and overwhelmed. Seeking a solution, she turns to a nurse who suggests trying a special cradle designed to help babies sleep better. Intrigued, Anna decides to explore this option further.

1. Research and Discovery:
Anna begins researching the recommended baby cradle. She finds information online about its features, benefits, and positive reviews from other parents who have used it. The cradle claims to provide a soothing and secure environment for babies, promoting longer and more restful sleep.

2. Rental Option:
Anna discovers that she can either buy or rent the cradle. Given her uncertainty about whether it will work for her baby, she decides to rent it for a month as a trial period. The rental option allows her to assess its effectiveness without committing to a long-term purchase.

3. Using the App:
After renting the cradle, Anna downloads the accompanying app that provides guidance on how to use the product effectively. The app offers step-by-step instructions, safety precautions, and tips for maximizing the cradle's benefits. It also provides useful information about infant sleep patterns, soothing techniques, and general baby care.

4. Testing and Relief:
Anna starts using the cradle as instructed by the app. She places her baby in the cradle during nap times and throughout the day when the baby needs extra nearness. To her relief, she notices that the baby is more calm and content in the cradle. The gentle rocking motion and snug environment seem to help the baby fall asleep and stay asleep for longer periods.

5. Rest and Recovery:
With the baby spending more time in the cradle, Anna finally gets some much-needed rest. She uses this time to recharge, catch up on sleep, and attend to her own essential activities. The extra moments of respite enable her to better care for herself, making her more equipped to care for her baby's needs.

6. Decision to Purchase:
After a month of renting the cradle, Anna reflects on the positive impact it has had on both her baby's sleep and her own well-being. She decides to purchase the cradle to continue benefiting from its features and support. She recognizes that investing in the cradle is an investment in her own and her baby's quality of life.

By exploring the scenario of Anna discovering and utilizing the rented cradle, we witness how it provides her with some much-needed relief and support during a challenging phase of motherhood. The app serves as a valuable resource, guiding her through the process and empowering her to make informed decisions about her baby's sleep and well-being.

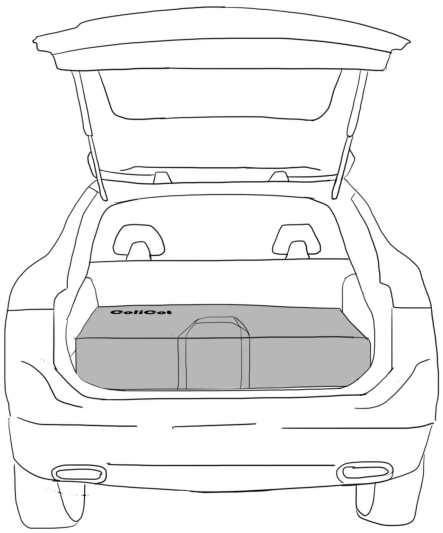



Figure 37: Anna transporting cradle to parents house

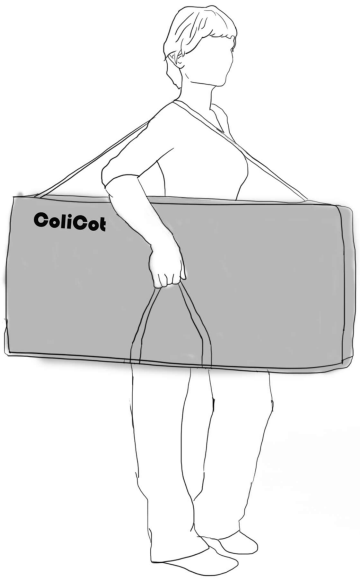



Figure 38: Anna is able to lift the cradle alone

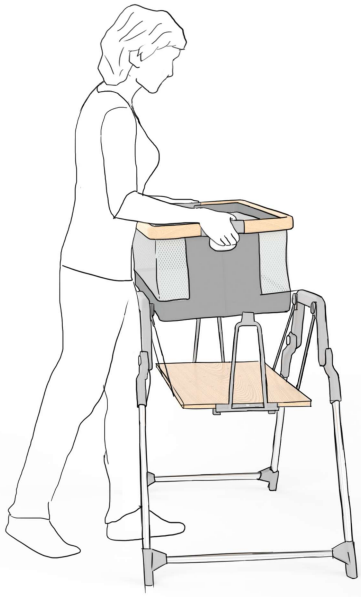


Figure 39: Anna assembling the cradle

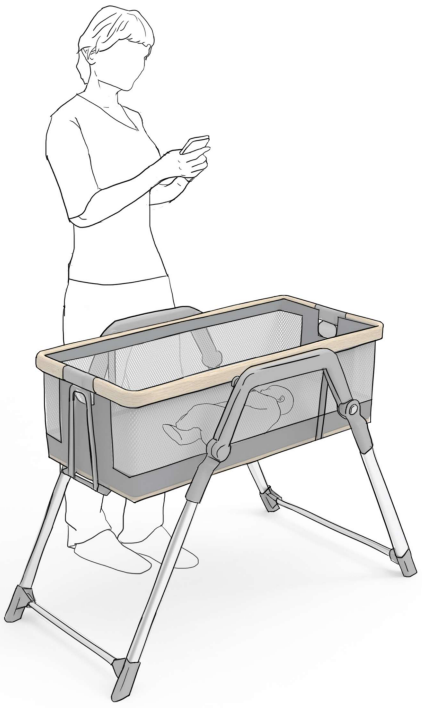
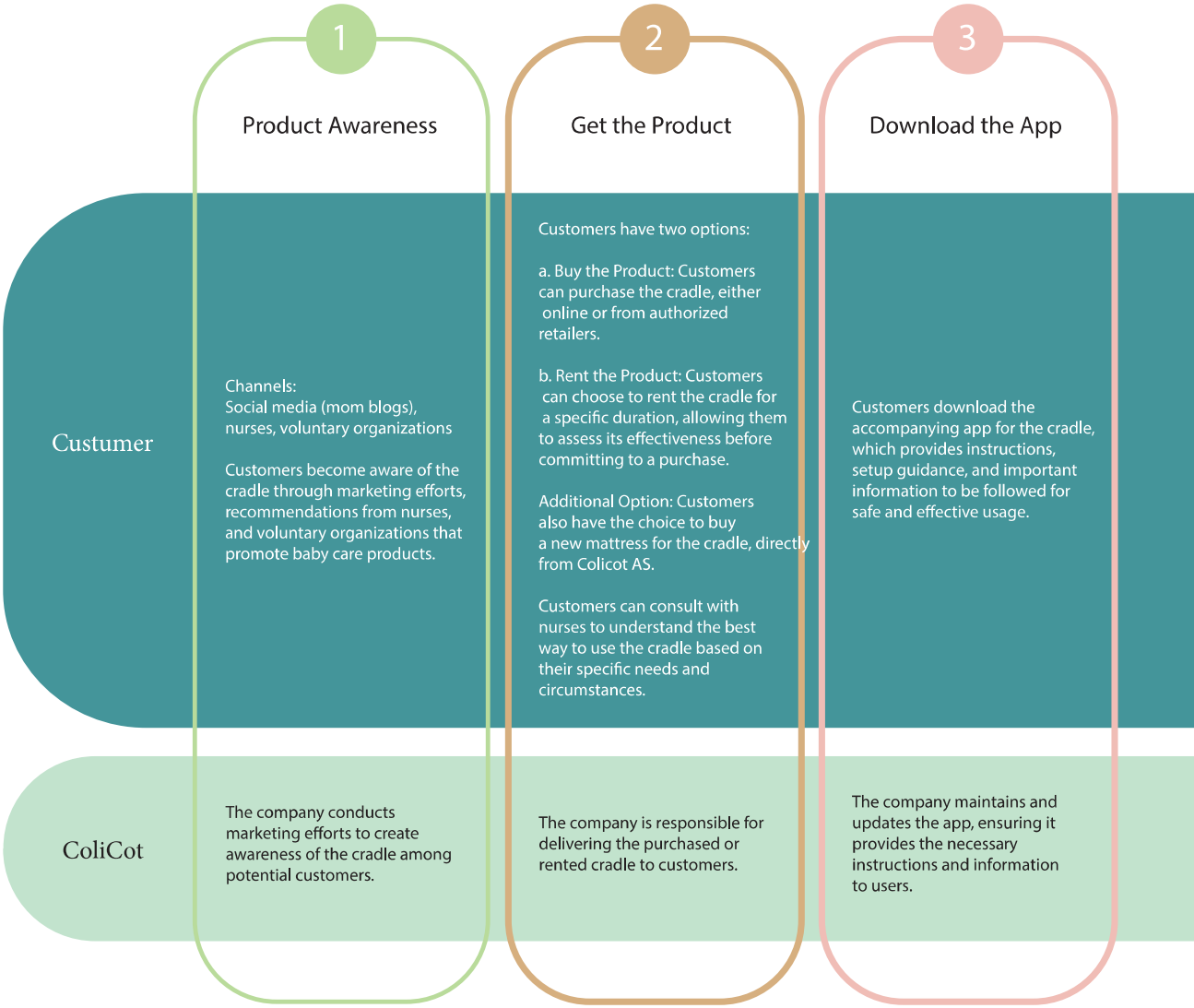


Figure 40: Anna use the cradle in combination with the app

## Service Design Blueprint for the Cradle:

This service design blueprint outlines the key steps and interactions involved in the customer journey of obtaining, using, and returning the cradle, as well as the corresponding responsibilities of the company. It emphasizes the importance of product awareness, customer support, and maintaining the quality and cleanliness of the cradles.



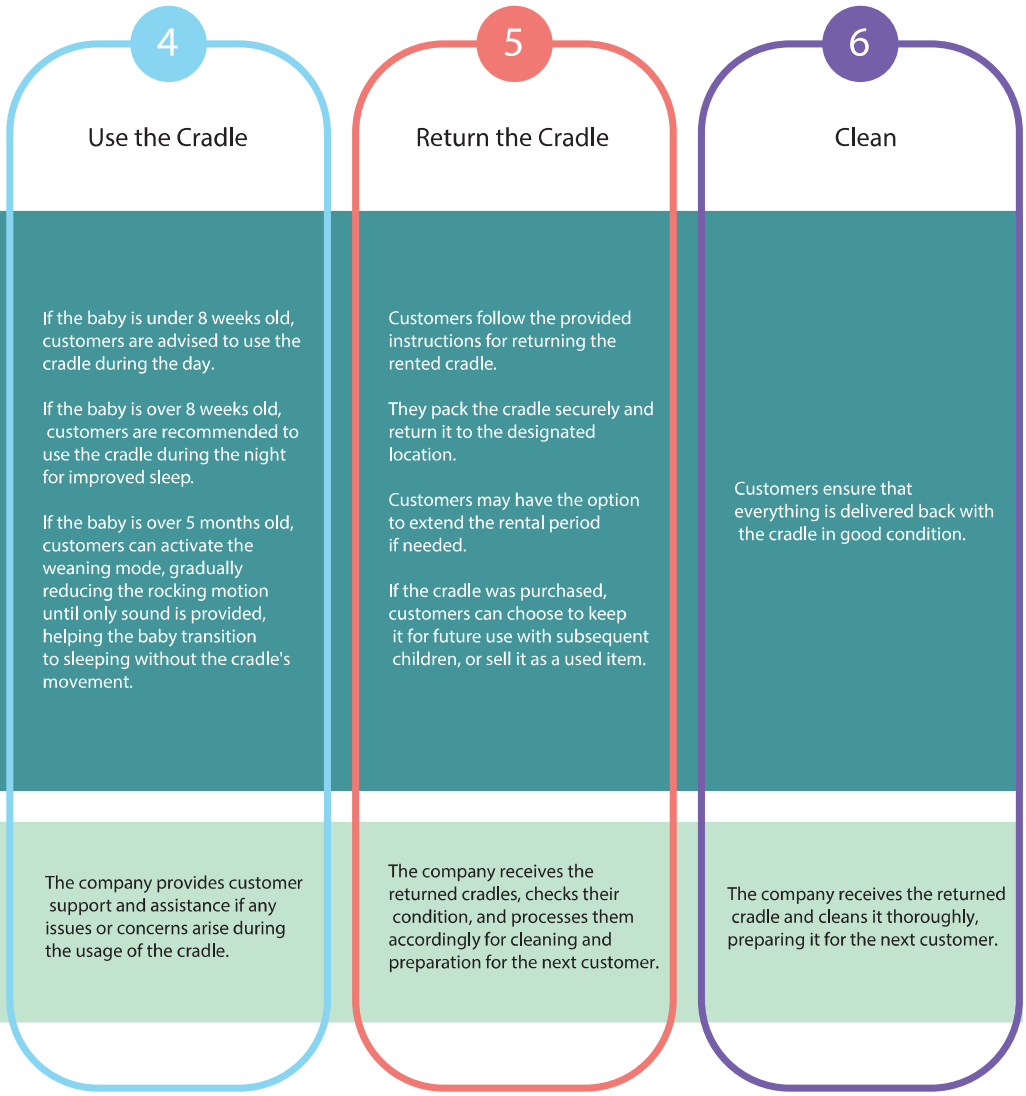



Figure 41: Service Blueprint

## Ecosystem and stakeholder map:

Understanding how a product fits within the larger system is crucial for its success. By considering the broader ecosystem, we can gain valuable insights into the various stakeholders and elements that interact with the product. This understanding enables us to design and develop a solution that addresses the needs and requirements of all parties involved.

By comprehending the wider context, we can develop a product that not only meets the immediate needs of its users but also contributes positively to the overall ecosystem. This approach fosters innovation, enhances the product's value, and increases the chances of successful adoption and integration into the market.

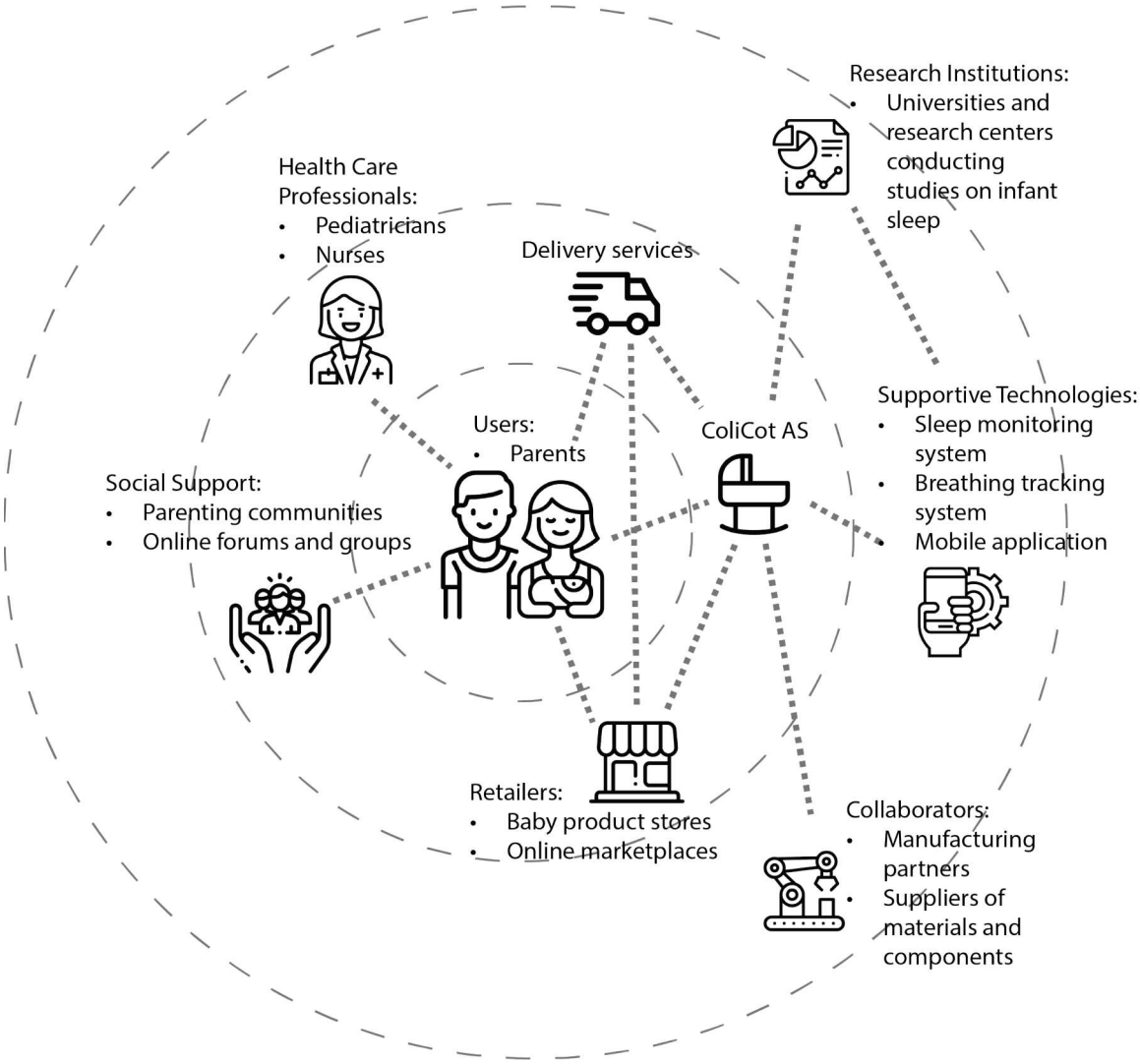



Figure 41: Ecosystem and skateholder map

## Testing and evaluation:

### User test with parents:

In the testing phase involving five participants on informal interviews, their feedback shed light on various aspects of the cradle's usability. When asked about the ease of moving the cradle around, all participants agreed that while it was "a bit heavy," but it was surprisingly effortless to maneuver. They found the handles intuitive to grasp, enabling smooth mobility. Connecting the cot to the base structure was reported as very easy and received positive feedback.

However, participants encountered some difficulty when assembling the legs of the cradle. Despite this challenge, they expressed satisfaction with the two-step lock mechanisms implemented in both the cot and legs, recognizing their importance for safety purposes.

Regarding the height of the cradle, participants found it to be ideal, striking a balance between not being too high or too low. Furthermore, when observing the cradle in its folded state, participants appreciated its compactness, as it occupied very little space and could be effortlessly transported in a car.

Overall, the feedback from the testing phase indicated positive impressions of the cradle's maneuverability, ease of cot attachment, safety features, optimal height, and compact design, while also highlighting the need for further attention to the ease of leg assembly.

### Results of testing structure and connections:

The current design of the cradle exhibits a flaw wherein it moves in the wrong direction. Upon closer examination, it appears that the updated method of connecting the cot to the straps and structure is prone to bending, leading to unintended oscillations in the incorrect direction (as depicted in the figure 42). This issue necessitates a redesign of the connection mechanism, incorporating a joint that allows for controlled oscillation in the desired direction. Furthermore, it should be noted that the weight placed on the cradle has an impact on these oscillations, making the current prototype unsafe for use with infants.

Regarding the folding mechanism, it holds promise in terms of space efficiency and user-friendliness. However, further development and user testing are crucial to fully optimize its functionality. The current structure of the folding mechanism exhibits insufficient strength, leading to undesired bending. To address this, implementing aluminum legs in the prototype could improve its overall robustness. Additionally, certain structural adjustments, such as raising the horizontal tubes on the legs, have the potential to enhance stability and performance. These modifications will require further exploration and testing to ensure an effective folding mechanism for the cradle.

Figure 42: Connection that needs to change

## Colicot future development plan:

During the prototype creation, I also create a development plan based on the insights gained from the initial research phase.

**Phase 1: Cradle Prototype and verification**

During this project I has already achieved some milestones, including:

- Create a new concept with the context of a service and a private product.
- Test different actuators that can be used.
- Create a first iteration for the new design.

Remaining tasks for this phase:

One of the most important steps for enabling the success of this product is to develop a high-fidelity working prototype that proves that the movement indeed helps the baby sleep. This include:

- Develop the 2 step locking mechanism
- Iterate on the design to get best possible results.
- Simulate the usage, movements and triggers to the movement. This can be done with a microphone and a motion detection sensor.
- Developing a test app. Do not need the processing on the system, it can be done on a cloud.
- Start to develop an ultrasonic sleep tracker system, but for the further development of the prototype, detecting the change of the movements of the infant in combination with noise is enough to activate the cradle.

**Phase 2: Smart baby cry algorithms and product testing**

- When Colicot has a high-fidelity working prototype that proves its efficiency, the cradle needs to be tested according to the safety requirements and after that can be ready for preparation to production.
- Colicot needs to prepare a marketing and partnership plan to make the product able to succeed.
- Develop ultrasonic sleep tracker system.
- Full development of the sleep tracker and breathing tracker.
- Fully develop the app. Maintenance and developing plan.
- Develop the embedded electronics, It is best that the processing happens local on the unit. Having processing on board means that there is no delay to trigger the movement of the cradle, and it is not internet dependent.

# 06

# DISCUSSIONS AND FUTURE

## 6.1 Addressing RQs:

***RQ1: To investigate design of baby cradles for better mobility and addressing needs of user context.***

To address the research question at hand, the first step involved understanding the context in which the cradle would be utilized. This entailed examining previous master theses, articles on existing cradle designs, and exploring parents' experiences through papers and interviews. Through this process, it became evident that the previous design, intended for infants with colic, had significant drawbacks in terms of mobility, durability, and user experience.
As a result, it was identified that expanding the target user base and positioning the product as a service would offer greater value. This shift required the creation of new design specifications that indeed to be adapted to the expanded user context.

A product development phase commenced, leading to the conceptualization of a new cradle design and the subsequent creation of the prototype for a new cradle. This fresh design exhibited improvements in terms of mobility, storage, and ease of cleaning compared to its predecessor. However, further development is necessary to refine its functionality.
Feedback received from individuals who assessed the design was positive, with praise directed toward its size, mobility within the house, and ease of transportation. Nevertheless, there remains a need for additional investigation to enhance the user-friendliness of the assembly process.

Considering the user context, I am confident that this design has the potential to meet the diverse needs of users. However, further investigation, development, and testing are still required to ensure its overall success..

***RQ2: To design home care services for Colicot which are connected with existing public health services.***

To explore the research question, I generated early concept ideas by using various public services. These ideas were then presented to a nurse, a company specializing in medical aids, and the head of a clinic department. Concerns were raised regarding the potential classification of the cradle as a medical device and the need for further specification of its purpose. While these stakeholders acknowledged the positive aspects of incorporating the cradle into existing public health services, they highlighted the potential challenges associated with such integration.

As a result, the development of the cradle took a different direction, focusing on private use. In this scenario, ColiCot would assume responsibility for distributing the product and managing the services surrounding it. However, despite not being distributed by existing public health services, collaboration between ColiCot and healthcare services remains essential. Nurses emphasized the importance of parents learning effective techniques to help their babies sleep, and for healthcare professionals to recommend such a product, it would require cooperation and certification to demonstrate the cradle's effectiveness.

The success of the cradle is contingent upon obtaining the approval and support of these stakeholders. Collaboration with healthcare services is vital, as it not only ensures the credibility and efficacy of the cradle but also contributes to its overall success. The cooperation between ColiCot and healthcare providers plays a significant role in establishing the cradle as a trusted solution for parents seeking assistance with their baby's sleep.

## 6.2 Limitations and reflection of the project:

As I reflect on the design process, it becomes crucial to assess the decisions I made throughout the journey. The insight phase of the project involved several changes in focus. The research questions were reworked to ensure alignment with the project's goals and my own skills, prioritizing the pursuit of the right solution to the right problem. The project encompassed various multidisciplinary phases, including service design, mechatronics, prototype building, CAD modeling, and app development. Seeking assistance from the institute, other students, and learning from their expertise played a significant role in my progress.

Working alone on such a project has posed challenges, particularly in terms of time management and resource allocation. The ability to divide tasks among team members could have significantly benefited the project, leading to a more refined prototype and concept. However, I was fortunate to receive valuable guidance and advice from my tutors, which compensated for the absence of a team.

Given the limited timeframe of just one semester for this project, decision-making was critical. It was essential to prioritize tasks and utilize my time efficiently. Seeking advice and assistance when necessary was also crucial in overcoming time constraints.

Overall, I am satisfied with the outcome of this project, considering the limited time available for its development. I hope that the progress made during this project will contribute to the future development of the final product.

## 6.3 Future work:

Given more time would like to be able to create multiple iterations, focusing on refining the locking mechanism, functionality and user friendliness during assembling, enough to make a high-fidelity prototype. Furthermore, I would like to test the prototype effectiveness. By being in contact by email with Torstein Baade Rø, vice-dean research professor of the Faculty of Medicine and Health Sciences at NTNU, it becomes evident that the testing of the cradle has challenges. As a recommendation, he suggested involving a new supervisor from the Faculty of Medicine and Health Sciences to assist in overcoming the necessary steps for conducting research of the cradle to prove its effectiveness.

## 6.4 Practical tips for designers for innovating products and services in the area of healthcare.

Here are some points that other designers working on similar projects could benefit from:

Prototyping:

- Prioritize understanding Arduino libraries before purchasing or sourcing parts for prototyping. Familiarity with these libraries simplifies the prototyping process and significantly reduces the time required to create prototypes

Structure:

- The importance of time management and prioritization. Time limited projects need good structures and prioritization lists to reach the desired goals.
- Utilize matrices to organize data. Visualizing data and choices can be challenging, but matrices provide a straightforward way to share ideas and decisions with others, facilitating effective communication.

Relations:

- The relation with health care needs to be close, involve them in the process if possible. To create innovation in the healthcare system innovation companies need to cooperate very closely, something that can become challenging.
- Don't hesitate to reach out to healthcare personnel. It may take some time to find individuals willing to engage, but there are always people within the healthcare system who are interested in projects and willing to help.
- Seek help from experts in other fields. As a designer, it's crucial to navigate different disciplines and never shy away from seeking assistance and opinions that provide different perspectives on the product.
- Recognize the importance of presentation skills for designers. Short, impactful presentations are crucial for generating interest in your project. A compelling pitch plays a significant role in the early development phase, especially when targeting individuals with limited time, such as healthcare professionals or innovation companies.

07

# CONCLUSION

## 7.1 Conclusion

In conclusion, the journey from research to the development of a prototype has been a transformative process. Throughout this project, I explored how the cradle could function as a service and identified the crucial factors that needed consideration. Through extensive research and user feedback, it became evident that the cradle had the potential to incorporate a broader range of parents, including those with colicky infants, thereby expanding its user target. Additionally, I recognized the significance of matching the cradle's functionality to the changing sleeping patterns of babies.

To refine the concept, I presented my ideas to professionals and incorporated their valuable feedback. I redefined the purpose of the cradle and created design attributes to compare and evaluate different designs, aiming to identify those with the highest potential. Following CAD testing and thorough comparisons against the attributes, I concluded that the shown design held the most promise.

Ultimately, the creation of the prototype represents the practical application of my findings. Although the prototype is not yet complete and requires further refinement and testing, it serves as a promising starting point in representing the potential of a final design. It demonstrates the progress made thus far in translating research and design into a tangible form, paving the way for future iterations and improvements.

# ACKNOWLEDGEMENT

## Acknowledgement:

I would like to express my sincere gratitude and appreciation to the following individuals and organizations who have played a significant role in the completion of this thesis.

First and foremost, I would like to thank my dedicated tutors and professors Ashis Jalote Parmar and Terje Rølvåg for their unwavering support, guidance, and invaluable feedback throughout this research journey. Their expertise and encouragement have been important in shaping the direction and quality of this work.

I extend my thanks to VitalThings for their collaboration and valuable insights. Their feedback was crucial to understanding how healthcare innovation companies work. Special appreciation goes to Ole Johan Ellingsen for their willingness to share their knowledge and experiences, which have greatly enriched my understanding of the subject matter.

I am deeply grateful to the nurses who participated in the interviews for their time and willingness to share their perspectives and expertise. Their contributions have provided valuable firsthand insights and have been crucial in shaping the findings of this project.

At last I would like to thank all the participants of the interviews and user testing for taking the time, and helping me to gather important data.

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# APPENDIX

**Bakgrunnsinformasjon til VAPA-vugge**

Av Eirik Andersen og Cecilie Kjellevold, 09.06.2010

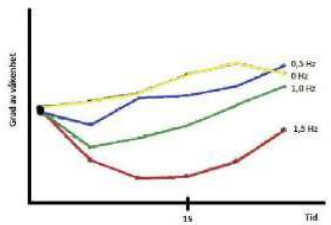
**Bevegelsesmønster.**

Det er gjort få studier for å finne ut hvilke faktorer som gjør at en vugge er en effektiv metode for å få små barn til å sove. Men det som finnes av forskning innen området peker i samme retning.

Bevegelsesmønsteret til en vugge kan deles inn i tre deler:

**1. Frekvens**

En forsøk fra University of Western Ontario ble i 1973 gjort for å teste hvilke frekvenser som fikk 64 stk 2mnd. gamle spedbarn raskest i søvn. Målinger av hjerterytme og visuell vurdering av barnets grad av oppmerksomhet viste at barn utsatt for 1,5Hz svingninger raskest falt i søvn. Grafen viser grad av våkenhet. Barna ble utsatt for svingningen i de første 15 minuttene.




Det er lite annen forskning på frekvenser påvirkning på spedbarn. Det mest av slik forskning er utført på voksne testsubjekter. Spesielt innen bilindustrien er dette aktuell forskning. Testene som er utført tilsier at voksne finner frekvense i overkant av 1 Hz behagelige. Man skal derimot ikke ha stor differanse før det virker direkte ubehagelig. Under 0.8Hz gjør testsubjektene kvalme og over 2 kan være skadelig. Ut i fra dette antar vi at svingninger kan ha den samme ubehagelige effekten på småbarn og det er derfor viktig å kunne kontrollere svingefrekvensen i en vugge nøyaktig.

**2. Amplitude**

Vi har ikke tilgjengelig noen rapporter som har fokusert på denne faktoren, men under forsøkene med ulike frekvenser var amplituden satt til 3" altså beveger vuggen seg +-4cm fra nullpunktet. Ved en frekvens på 1,5Hz, som gir en svingetid på 2/3 sek, høres dette ut til å være i det øvre sjiktet av hva som er behagelig amplitude ved denne hastigheten.

**3. Bevegelsesretning.**

De siste årene har vugger endret fra å bevege seg fra side til side til å vugge i lengderetningen. Dette skal være bedre for barnet og få det raskere i søvn. Det ville i tillegg vært interessant å vite hva som er det optimale rotasjonspunktet. Plassering av rotasjonssenteret vil også ha en effekt på hva som vil være optimal amplitude på svingningen. Rotasjon om et punkt vil kunne takle større amplitude enn rene lineære bevegelser i horisontalplanet.

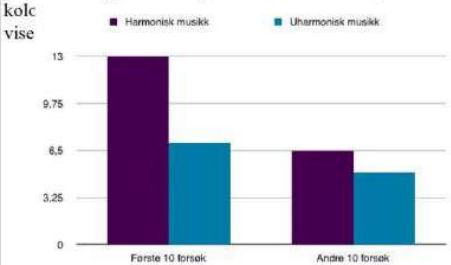
**Musikk:**

**Følelser i stemmen:**

Vuggesanger har vært brukt i alle tider for å dysse småbarn i søvn. Hvorfor den beroligende stemmen til far og mor roer ned spedbarn er det viktig å vite hvs man ønsker å erstatte sangen med musikk, og dette har det blitt forsket på. Undersøkelser har vist at en viktig del av vuggesangen er den menneskelige kontakten, barnet oppfatter følelsene i stemmen, men type musikk som synges eller spilles av er også en viktig faktor. Barn reagerer positivt på harmonisk musikk.

**Harmonisk og uharmonisk musikk:**

Figuren under viser en test hvor spedbarns oppmerksomhet rettet mot musikken som blir avspilt ble målt. Lilla kolonne er tiden barna var oppmerksom på harmonisk musikk, mens den blå kolc ene vise




**Klassisk musikk:**

Det har også blitt gjort tester på hvilken musikksjanger som er mest effektiv på småbarn og her kommer klassisk musikk godt ut. Klassisk musikk har generellt god påvirkning på hjerneaktiviteten til barn. Flere studier har vist at klassisk musikk gjør barn mer avslappet og gir klare helsefordeler. Rolig gitar musikk er brukt i studiet som er nevnt ovenfor, artister som Eric Clapton har rolig gitarmusikk som virker terapautisk og beroligende på både barn og foreldre. Og i en undersøkelse utført ved Nova Southestern University viste resultatene at tiden det tok for et spedbarn og sovne ble redusert med hele 30% når det ble spilt klassisk gitarmusikk mens barna sov.

Mean Sleep Onset Time (in minutes) During Naptime Music (no music) for Toddlers an Preschoolers

| | Music | No music |
|---|---|---|
| Toddlers | 16.9 | 26.0 |
| Preschoolers | 30.0 | 37.9 |

**Produsenter:**

1. Stokke - Kjent for skandinavisk design kombinert med god funksjonalitet. VAPA-vugge ser ut til å være et produkt som passe godt inn i deres produktsortiment. stokke.com/no-no/contact-us.aspx

2. Simo og Brio - Delvis sammenslått i firmaet European Nursery Group AS. Markedsledere i Skanidnavia innen barneutstyr. Har fra før et stort utvalg av vogner og barnesenger. konsument_no@engbaby.com, info@brio.net

3. Graco og Fisher-Price - Store amerikanske produsenter av barneutstyr med et svært bredt sortiment. Begge har allerede en del ulike motoriserte husker/vugger fra før, men "plast"-faktoren på disse er høy og innovasjonshøyden lav. fpconaff@Fisher-Price.com

4. Britax I asjonal produsent av sportsvogner, bilseter m.m. Har ikke noen form for barneseng i sortimentet. service.no@britax.com

5. SO-RO - Vugger med norsk design og produksjon, men svært rettet mot design. service.no@britax.com

| Title: Virtual Adjustable Pivot Axis Vogge ( VAPAV ) | | Dato: 18/09-2010 |
|---|---|---|
| Keywords: VAPAV baby cradle | Written by: Terje Rølvåg | Reference: Input to VAPA cradle design |

**Current situation:**

*Infant cradles are designed to comply with traditional rules. That means sideways motion (roll), handcrafted designs, traditional wood and no additional features stimulating sleep.*

*All cradles have one roll degree of freedom. That make no sense since roll motion tend to make babies seasick rather than tired. The roll motion also creates an unwanted sideways baby translation since the roll axis is located below the cradle. Here is one typical design:*

*Research [1,2,3] indicate that coupled longitudinal and vertical oscillations with 2-3 cm amplitudes, in the frequency range of 1-1.5 Hz, make kids fall asleep. Unfortunately, no existing cradle designs enable this motion.*

**Solution:**

*The patented VAPA mechanism concept enables the desired cradle motion. The invention is based on one or two flexible 2D structures. The flexible structure allows two translational and a flexible tilting rotation about a virtual pivot axis (3 degrees of freedom / DOF's).*


*The tilting stiffness is given by the geometry and thickness of the flexible 2D structure.*

*The direction of the pivot axis is defined by the two pivot points or the surface normal of the flexible structures. The centre of rotation is given by the geometry and can be outside the volume of the flexible structure itself.*

**VAPA Benefits:**

***Cradle motion that makes the baby fall asleep.***

*•The tilting characteristics are optional, and by locating the pivot axis above the cradle the baby will feel like sleeping in a hammock.*

*•The tilting characteristics is simply altered by selecting different flexible structures giving the cradle an eigenfrequency in the desired range (1-1.5 Hz).*

*•The amplitude (2-3 cm) can be controlled by an actuator located under the cradle. The structures also have linear tilting characteristics until self contact occur (can be limited to 3 cm). Then it still allow flexible motion but the stiffness increase.*

***Other sleep-inducing factors.***

*• VAPA may include sound and display systems for visual and auditive effects simulating any environment . It is proven that some music, running cars and trains are sleep inducing factors [2]. I would like to add a wide range of movies ...*

***Scalable design***

*•VAPA can be designed for both infants, babys, larger kids and adult insomnia patients. The flexible structures can be dimensioned for any load and application*

***Modular design.***

*•The VAPA cradle is a platform solution with many optional add-ons adding functionality and comfort. The VAPA cradle can be market as a modular or a high end integrated cradle system as shown below.*

*The VAPA frame give you the desired longitudinal and vertical cradle motion!*

*An actuator creates resonance at the right frequency (1-1.5 Hz)*

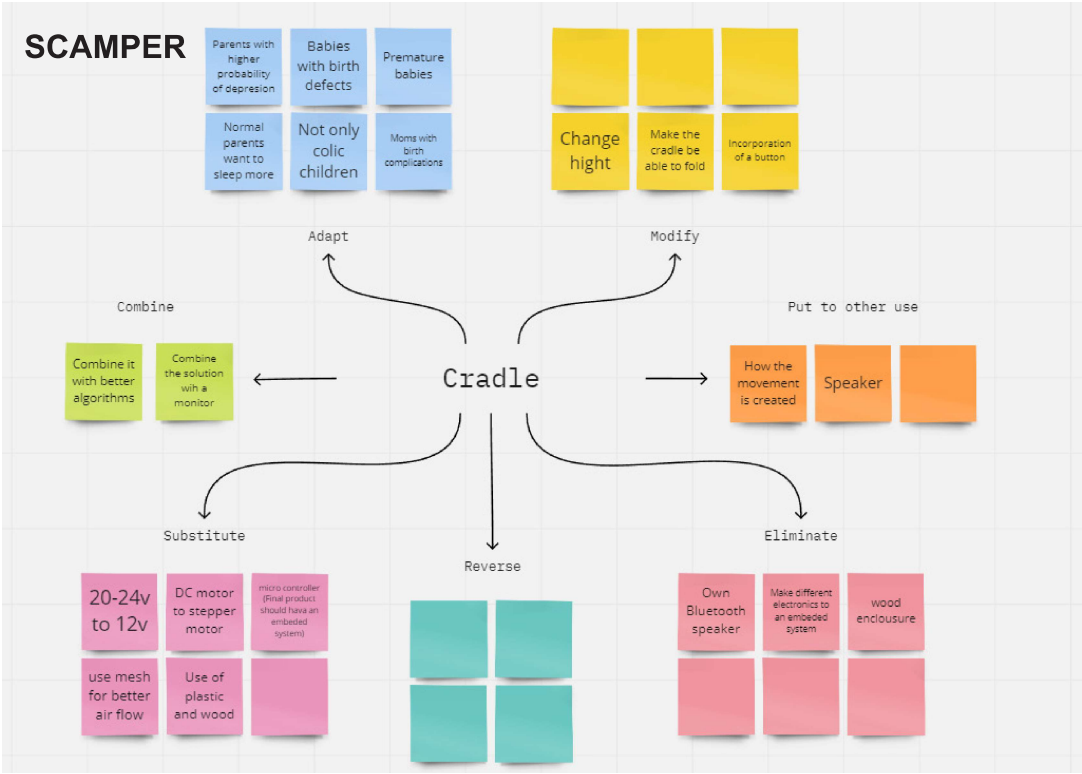
*Any bag or custom bouild cradle can be used with WAPA.*

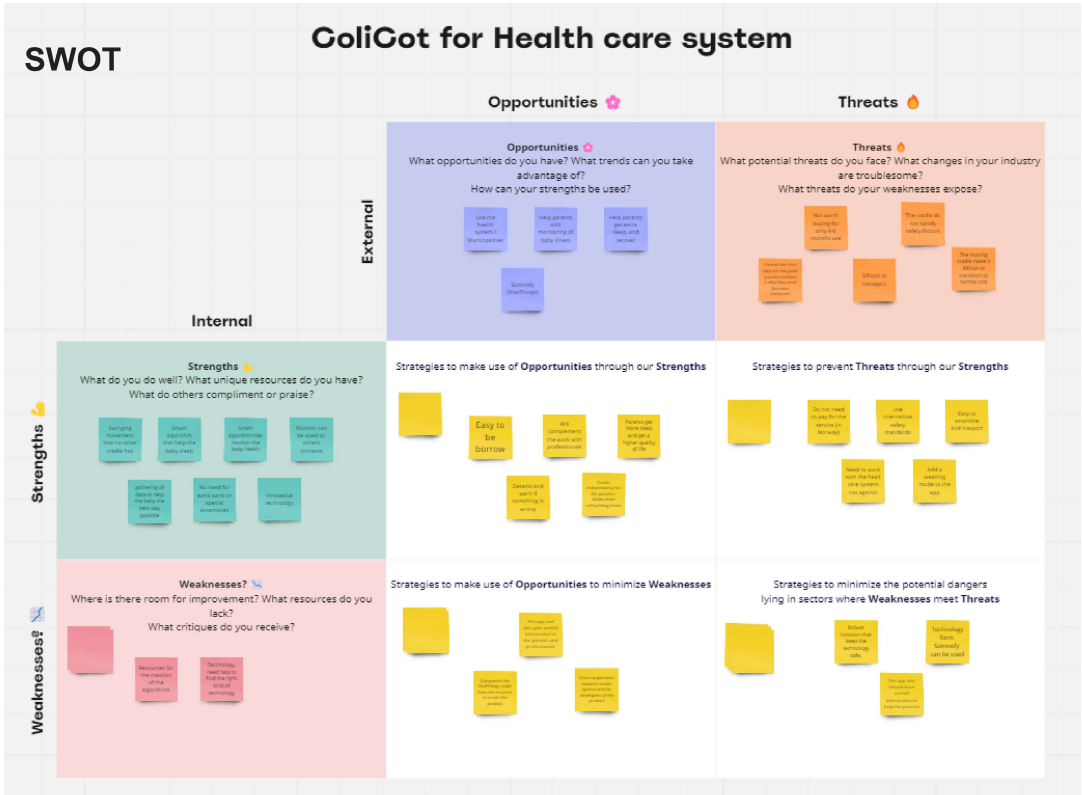
*Add loudspeakers and a monitor to simulate any environment*

***References:***

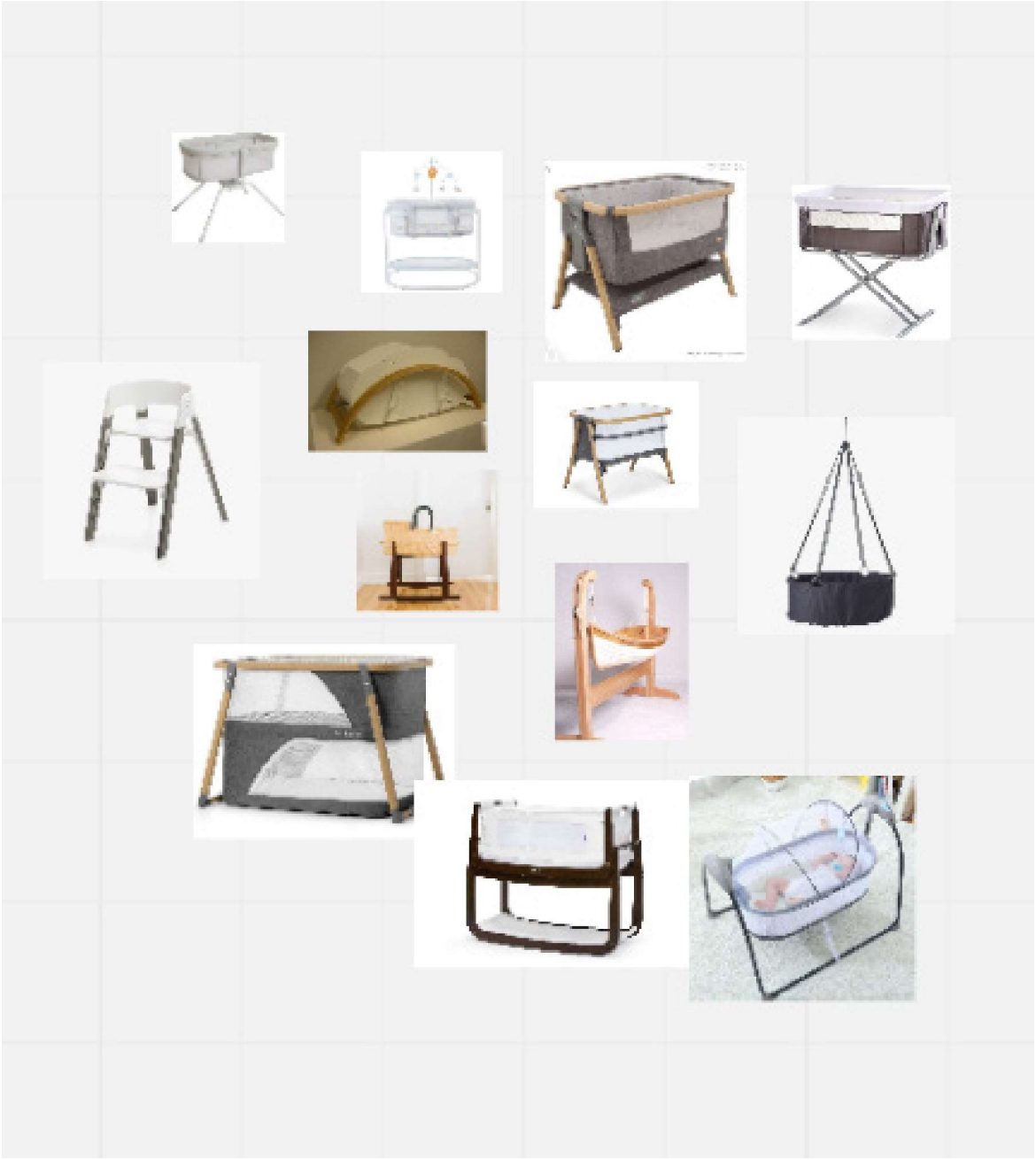
*[1] Hitoshi Kimura, Mami Endo, Michihiko Koseki and Nori Inou, Tokyo Institute of Technology, Dept. of Mechanical and Control Engineering,"Sleep-inducing factors in mechanical environments", Journal of Environment and Engineering, Vol 5, No 2, 2010.*
*[2] David R Pederson, University of Western Ontario", The soothing effect of rocking as determined by the direction and frequency of movement".*
*[3] Yvonne Backbill, Georgetown University Medical School, "Continous stimulation reduces arousal level, stability of the effect over time".*

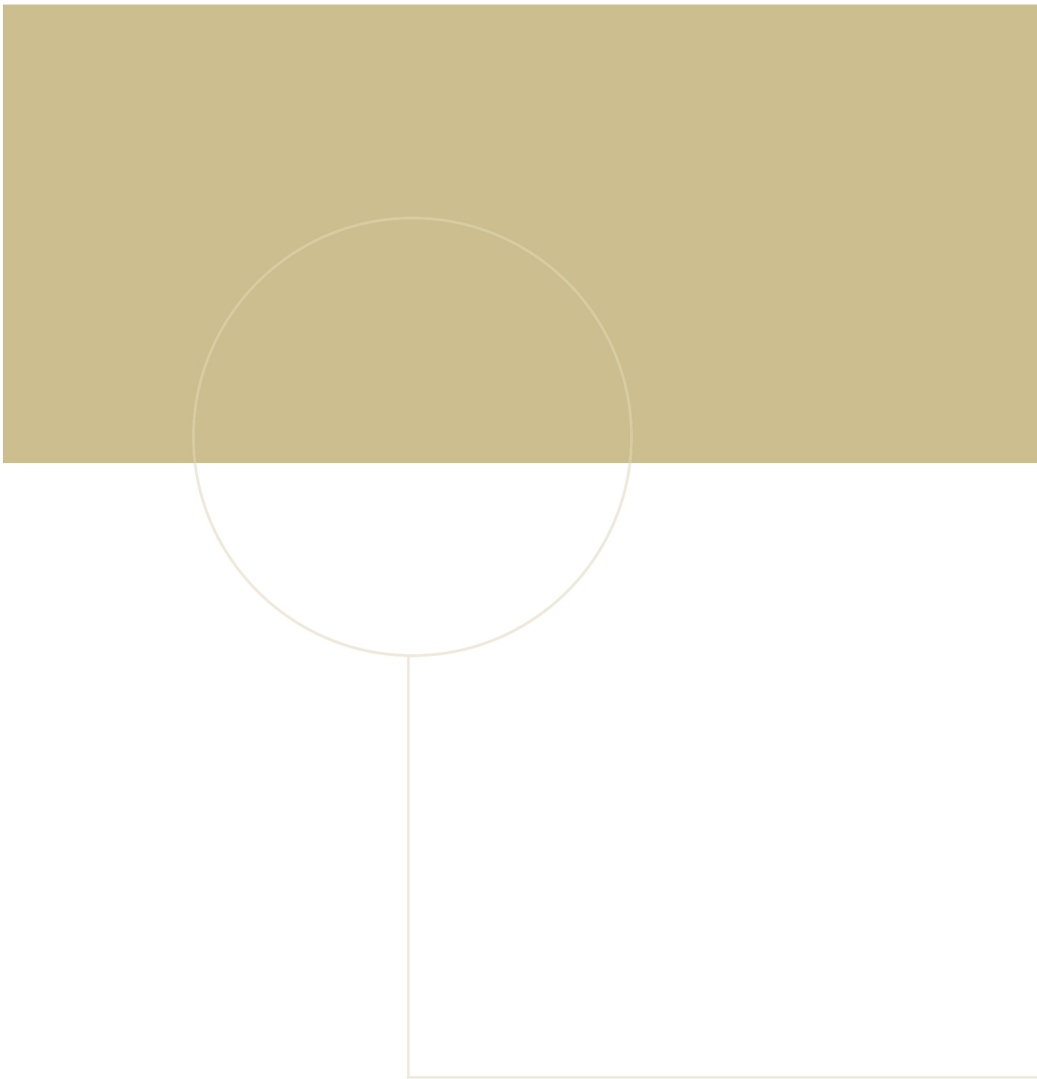
# Appendix C - SCAMPER and SWOT



## Appendix D - Moodboard





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